

COST and EFFECTIVENESS of Different Insect and Disease Control Practices in New York Apple Orchards

H. Von Oppenfeld D. Boynton

J. L. Brann A. B. Burrell E. S. Shepardson



CORNELL UNIVERSITY AGRICULTURAL EXPERIMENT STATION

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Summary

1. Records of cost of spraying and pest control in relation to spraying equipment, materials, and practices were taken in more than 100 commercial apple orchards of western New York and the Hudson Valley in 1949 and 1950.

2. The major spray machinery classifications in the study were (1) dilute air blast, (2) concentrate air blast, (3) high pressure with guns and/or brooms, (4) high pressure with masts or spray heads.

3. Size of business was related to type of equipment used; high pressure sprayers were used mainly on the smaller operations, and, although dilute and concentrate airblast equipment was used on farms varying greatly in size, 11 of the 13 largest orchards had airblast machines.

4. The number of gallons applied per hour averaged highest for the blocks using dilute airblast equipment, and lowest for the blocks using high pressure sprayers with guns and brooms.

5. For dilute spraying operations, the time of the individual spray cycle was in the fastest group when (1) the pump size rated 50 gallons per minute or more, and was used to approach its rated capacity, (2) non-spray time was kept to a minimum by uninterrupted spraying while the spray machine was in the orchard, (3) travel time was minimized by use of transport rigs, or by convenient stationary water supply, (4) filling time was minimized by provisions for rapid transfer of water and mixing.

6. Weather conditions had an important influence on insect and disease problems: 1949 was relatively dry, and 1950 relatively wet; codling moth was more difficult to control and scab was less difficult to control in 1949 than in 1950.

7. Pest control was less satisfactory on trees higher than 20 feet and on trees with dense foliage, regardless of machinery.

8. There was a suggestion in the data that very rapid output (more than 1200 gallons per hour) may sometimes be associated with inferior control, due perhaps to excessive rates of travel during spraying.

9. More sprays, and more gallons of spray, were used by growers who permitted scab to become serious early in the season than by those who minimized the primary infection by thorough coverage with timely sprays in the spring and early summer.

10. The use of organic fungicides instead of sulfur did not, on the average, increase the effectiveness of scab control.

11. The total cost per acre of spraying decreased as the total acreage of bearing trees increased.

12. Of the average cost of spraying per acre (\$98.00), 63 per cent went for spray materials, 10 per cent for labor, 7 per cent for tractor power, and 20 per cent for spray equipment.

13. On the average, the dilute and concentrate airblast spray equipment classes had lower per acre labor costs and higher machinery costs than the high pressure classes. The average total costs for the four main equipment groups were not very different, although the concentrate airblast group had the lowest total in 1950, due to relatively low labor and low materials costs.

14. The ranges in cost per acre were far greater within each machinery class than between the classes.

15. The spray materials cost per acre varied from less than \$30 to more than \$120 per acre. The main causes for high materials costs were: (1) large numbers of sprays and total gallonage, (2) expensive organic fungicides. Growers with low potential infestations of pests, excellent timing, and thoroughness of application in early sprays, and who used the less expensive materials, had the lowest materials costs per acre.

16. The spray cost per bushel of marketable fruit ranged from less than \$0.12 to more than \$1.89. The blocks with high yields, excellent pest control, and low index of spray cost had the lowest spray costs per bushel.

17. No general specifications may be set up for reducing the cost of spraying in all orchards on the basis of this study. The kind of spray machinery, water supply facilities, labor saving devices, and spray materials that were best for a particular orchard depended on its size, physical problems, and pest control problems. While large investment in the most modern spray equipment was sound on some operations, it was not necessary or economical on others. Basic to all low cost spray programs were high yields and a high degree of pest control.

Cost and Effectiveness of Different Insect and Disease Control Practices in New York Apple Orchards

by H. von Oppenfeld, D. Boynton, J. L. Brann,
A. B. Burrell, and E. S. Shepardson

The control of insects and diseases is one of the most important operations determining the success of an apple orchard. It is also the most expensive production operation, accounting for about 40 per cent of the total cost per acre of growing the fruit. The per acre cost of insect and disease control has increased greatly in recent years (Appendix table 1), and in this period of rising cost there have been revolutionary developments, both in the kinds of spraying machinery and in the toxicants available.

In recognition of the need for information on the subject, a preliminary study of cost and efficiency in spraying apples was made in 1946 by K. L. Robinson.¹ Records taken in 50 western New York orchards one summer and fall were the basis of the study. Of the 50 operations, 43 were sprayed with high pressure machines and 7 were sprayed with airblast machines; all orchards were sprayed with dilute solutions of toxicants. The effectiveness of insect and disease control was rated mainly by rather extensive observations, rather than by detailed examination owing to limited manpower. Major emphasis was placed on the operating efficiency of the machines, as influenced by the type of machine, water supply, filling, and nozzle equipment. The study showed conclusively that considerable increases in efficiency with accompanying decreases in cost, but without decreases in control, could be made in many of the operations concerned. It also emphasized the complex interrelationships between the cost and the control factors, and suggested the need for more intensive study.

Within the next three years airblast equipment using dilute solutions of toxicants became more common, and greater interest developed in the possibilities of airblast equipment using concentrated suspensions or solutions of toxicants. Experimental concentrate machines were supplanted by commercial models, and there was a need for information on the relative efficiency and effectiveness of spraying operations using such machines under commercial conditions. New expensive organic toxicants were available for use in combatting insects and diseases; their effects on cost and control were not yet measured under commercial conditions.

¹Robinson, K. L. Cost and efficiency in spraying apples. Thesis for degree of M.S., Cornell Univ. (Unpublished.) July 1947.

This survey was made to evaluate (1) the kind of spray equipment and materials used, (2) the efficiency of operation, (3) pest control and cost of spraying under the conditions of 1949 and 1950. Because of the need for specialized information over so broad a front, the study was made by five departments in the New York State College of Agriculture: Agricultural Economics, Agricultural Engineering, Entomology and Limnology, Plant Pathology, and Pomology. More than 100 fruit growers of the state made their orchards and equipment available, and took detailed records of spraying operations.

Procedure

The survey was conducted in apple orchards of the Hudson Valley and western New York in 1949 and 1950. In 1949, 103 individual apple blocks operated by 98 growers comprised the number whose records were used in the final analysis. Sixty-four of these blocks were in western New York, 38 were in the Hudson Valley, and one was in an outlying county. In 1950, 116 blocks operated by 108 growers were included in the final analysis. Eighty-three growers cooperated in both years, and 74 blocks were used in the study in both years. Figure 1 shows the distribution of blocks by counties for 1950.

The blocks used in the survey were chosen on the basis of four criteria: (1) the kind of equipment used, (2) the predominant variety of apples, (3) the age and size of the trees in the block, (4) willingness of the grower to cooperate.

Kind of spray equipment

As even a distribution of equipment as possible among six general categories was desired. The general categories were (1) dilute airblast machines, (2) concentrate airblast machines, (3) high pressure machines using guns and/or brooms, (4) high pressure machines using masts or spray heads, (5) spray-dusters, and (6) wet dusters. As table 2 indicates, in 1949 only the dilute airblast and the two high pressure classes were large enough to warrant serious consideration of their averages. In 1950 it was possible to include enough blocks sprayed with concentrate airblast equipment to justify their separation in the cost tabulations, but there were very wide differences in the size and physical characteristics of the concentrate machines within the group. Also, the unfamiliarity of the operators with this new equipment placed them at a disadvantage relative to those operating other kinds of equipment. Many blocks included in the study were sprayed with several kinds of equipment, and only those which were sprayed 70 per cent or more of the time with the designated piece of equipment were included in that category; the rest were placed in the category "unclassified". Table 1 presents a detailed tabulation of the spray equipment classification for the 1950 blocks. Appendix table 2,

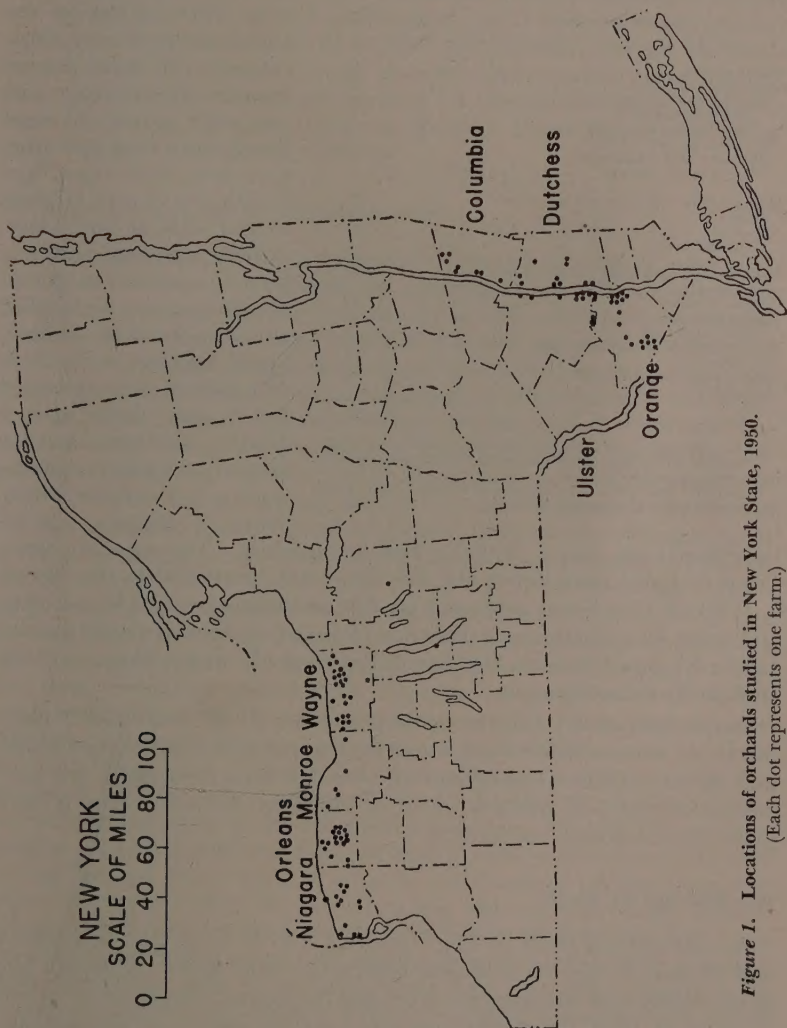


Figure 1. Locations of orchards studied in New York State, 1950.
(Each dot represents one farm.)

Table 1. Classification of the spraying equipment used in the 1950 survey blocks* (New York State)

Type of equipment†	Number of blocks	
Dilute airblast.....	..	38
Concentrate airblast.....	..	16
Fixed outlet high volume.....	..	..
Low concentration.....	3	..
More than 4x concentration.....	4	..
Fixed outlet low volume.....	3	..
Moving outlet mechanical.....	4	..
Moving outlet manual.....	2	..
High pressure with guns and/or brooms.....	..	23
Guns.....	15	..
Brooms.....	2	..
Guns and brooms.....	6	..
High pressure with masts or spray heads.....	..	20
Gun nozzles.....	11	..
Boom nozzles.....	3	..
Mixed nozzles.....	3	..
Oscillating heads.....	3	..
High pressure with various outlets.....	..	5
Wet dusters.....	..	4
Spray dusters, variously used.....	..	3
Unclassified.....	..	7
Total.....		116

*Classified on the basis of equipment used for three-quarters or more of the spray applications.

†A detailed description of the equipment included under these categories is made in appendix table 2.

gives more details about the machines placed within the various groups.

In 1950, of the 38 machines in the dilute airblast category, 21 were Speed Sprayers operating with one side open, 10 were Speed Sprayers operating with both sides open, and 7 included Hardy airblast, Friend airblast and Myers airblast sprayers and one home assembled outfit. Of the 16 machines classified as concentrate airblast, Speed Sprayers using 2x to 4x concentration accounted for 3, and there were 4 Hardie mist concentrate sprayers, 4 Lawrence Mistomatics, 2 Lawrence Mistomites, 2 Niagara concen-

trate machines, and 1 Buffalo Turbine machine. The mast or spray heads included Bean hi-boy and low-boy masts, Myers and Hardy booms, a Traverse City boom, and an Iron Age oscillating head. The wet dust and spray dust machines in the study included equipment manufactured by the Niagara Chemical Division of the Food Machinery Corp., and the Buffalo Turbine Company.

Supplementary dry dusting was done in many of the blocks under study, but it did not constitute a quarter of the control operations. In one block, dusting was practiced throughout the year, but since the control was poor and it was the only block handled in this way, the records for it were placed in the group "unclassified".

Size and age of block

An attempt was made to select blocks of 5 to 10 acres, and between 15 and 30 years of age, for intensive observation and record. Although size of the blocks used averaged 6.4 acres and the average age of the trees was 25 years in 1950, there were somewhat greater ranges in size and age than was originally planned. Thus the range in block size was 2 to 25 acres, and the range in age was 14 to 41. Some of the differences in tree age are associated with the differences in bearing capacity and number of trees per acre indicated in table 3.

Predominant variety

In so far as possible, blocks with McIntosh as the predominant variety were selected for the study. In 1949, 74 of the 103 blocks were classified as McIntosh. Of the 116 blocks in 1950, 106 included enough McIntosh trees to permit their use as "count" trees for determination of pest control and crop size. The other varieties used for observation included Rhode Island Greening, Cortland, Baldwin, Wealthy, Rome Beauty, and a few other standard commercial varieties.

Methods of gathering the information

The cooperating fruit growers kept daily records of their spraying practices in the selected block during the growing season. The date, weather conditions, amount and kind of materials used, equipment used, and number of hours of use were recorded for each spray. Each summer a member of the Agricultural Economics Department obtained from each cooperator information on the business aspects of the orchard as a whole that pertained to the cost of spraying. During one or both spraying seasons of 1949 and 1950 a member of the Agricultural Engineering Department visited each grower and made observations on the spray machinery, the tractor power, and the water supply equipment. In most of the blocks he also made a time and motion study of one complete spray cycle in the survey block, recording the time taken for mixing and filling, travel, and emptying the spray tank. A member of the Pomology Department mapped each of the survey blocks, recording varieties, spacing, tree size, tree density, bearing capacity, and estimated percentage of full crop; he also marked ten trees from which detailed records on control were to be taken. A member of the Plant Pathology Department recorded the apple scab lesions on the original rosette of spur leaves in June, and the scab lesions on leaves of terminals in midsummer. In late August and early September of 1949 and 1950, members of the Entomology Department, with the help of others, obtained a detailed record of the lesions on the fruit from four of the ten marked trees in each block that resulted from apple scab disease and from the insects codling moth, curculio, and red-banded leaf roller. For this purpose, from each of the four trees 100 fruits were taken from the top branches, 100 from the outer bottom branches, 100 from the lower inside branches of the tree, and 100 drops from the ground. The records for samples from each of the four locations were taken separately. In addition, these four trees were marked with string and tagged conspicuously so that the picking foreman could record yields of picked fruit and drops; these tags were collected after the harvest.

After analysis of the separate parts of this survey by each departmental cooperator, and after conferences, the tabulations most pertinent to this general report were selected. Much material not included here may either be found in the theses of four graduate students who worked on the

project^{2 3 4 5}, or will be published or disseminated separately. In the course of summarizing the data, three preliminary reports have been made to the New York State Horticultural Society^{6 7 8}, and each of the co-operating growers has been given information in each year on the relative cost and effectiveness of his spray program. One mimeographed report has also been made available.⁹

Limitations of the survey method

While this is undoubtedly the most exhaustive survey of its kind, there are general limitations in the survey method which should be foremost in the minds of those who attempt to interpret its results. They pertain to: (1) the representativeness of the sample and to its size, (2) the quantitative significance of the averages, (3) the heterogeneity of make and model within the broad equipment classes for which the averages were calculated, (4) the complex interrelationships among the various factors considered, and (5) the lack of information on insect and disease potentials. The orchards sampled were among the best in the state, and the cooperating growers were far above the average in management ability. Hence, the general sample was not representative of average conditions in New York orchards. The total numbers involved were small, and within each machinery category were so small as to be a minimal for statistically significant averages. Because of the great range in cost and control for the data averaged, the averages are of use mainly as indices of relative position rather than as absolute figures. The extremely complex interrelationships of the factors determining cost and control make interpretation of many of the simple tabulations presented subject to error of judgment. And likewise, because of these interrelationships, important factors involved in cost and control may be completely masked by more dominant ones in some of the tables presented. With these limitations in mind, the authors have attempted to interpret the results conservatively, realizing that correlation, or lack of correlation, may be due, in particular instances, to weaknesses of the method.

²Suter, R. C. A detailed cost study on methods of spraying apples, New York, 1949. Thesis for degree of Ph.D., Cornell Univ. (Unpublished.) 1950.

³Titus, J. S. The relationship among soil characteristics, foliage characteristics, and tree performance in eighty New York McIntosh apple orchards. Thesis for degree of Ph.D., Cornell Univ. (Unpublished.) June 1951.

⁴Von Oppenfeld, H. A study of factors influencing pest control and cost of spraying apples, New York, 1950. Thesis for degree of M.S., Cornell Univ. (Unpublished.) September 1951.

⁵Flynn, J. E. A study of factors which affect pest control on apples in New York state, 1949 and 1950. Thesis for degree of M.S., Cornell Univ. (Unpublished.) 1952.

⁶Hurd, T. N. Some findings of the 1949 spray survey. N. Y. State Hort. Soc. Proc. 1950: 119. 1950.

⁷Boynton, D., Brann, J. L., Burrell, A. B., Garman, C. G., Shepardson, S. S. A report on the cost of spraying survey. N. Y. State Hort. Soc. Proc. 1951: 76. 1951.

⁸Boynton, D., Brann, J. L., Burrell, A. B., Shepardson, E. S., von Oppenfeld, H. Cutting the cost of spraying. N. Y. State Hort. Soc. Proc. 1952. 1952.

⁹Cornell Univ. Dept. Agr. Engineering. Agricultural engineering aspects of spraying apples. Mimeo. Bul. 47. 1952.

Physical Relationships

Size of business

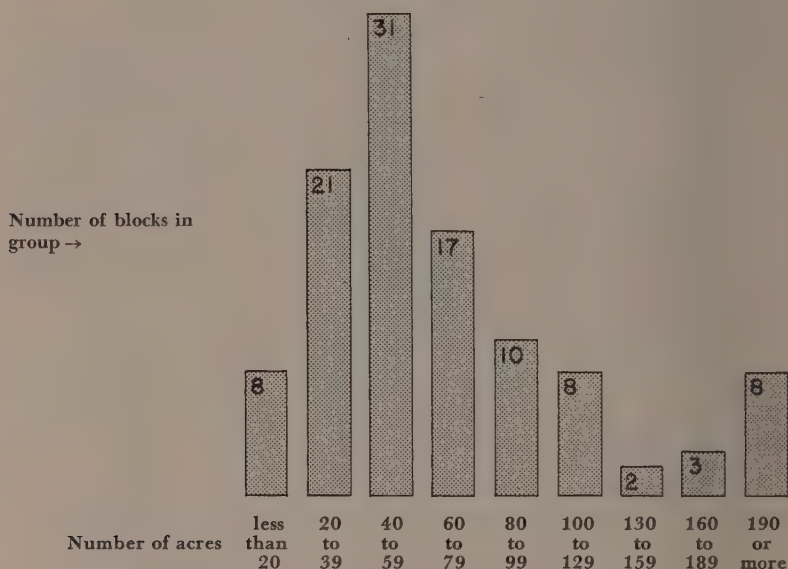
Records were obtained from 98 fruit farms in 1949, and from 108 farms in 1950. For 1950, these farms had an average of 71 acres of bearing apple trees, and 105 acres of total fruit (table 2). The New York fruit farms on which cooperative cost account records are kept are generally considered to be larger than the average in the state, and they averaged only 45 acres of bearing apples in the period from 1944 to 1948.¹⁰ Thus, the growers who cooperated in this project had fruit acreages well above the state average. They were also more specialized in fruit growing. Project growers in western New York had approximately the same acreage as those in the Hudson Valley. Acres of non-bearing apple trees in 1949 and 1950 were 14 and 13 per cent of the acreage in apples only.

In terms of averages, the size of a business was closely related to the type of spray equipment used. The average acreage of fruit was greatest on the farms using airblast equipment, dilute or concentrate, and was least on the farms having high pressure equipment with guns and/or brooms. However, as figure 2 shows, there was a very great range in size of orchard

Table 2. Acres of fruit trees on the survey farms classified according to the predominant spray equipment used in the selected blocks
(New York State)

Type of equipment used	Year	Number of farms	Average number of acres per farm		
			Bearing apples	Nonbearing apples	Total fruit
Dilute airblast.	1949	27	82	14	142
	1950	36	86	13	137
Concentrate airblast.	1950	15	114	9	136
High pressure with guns and/or brooms.	1949	34	52	8	78
	1950	23	41	3	64
High pressure with masts or spray heads.	1949	19	59	5	76
	1950	17	57	8	88
High pressure with various outlets.	1949	6	60	20	99
	1950	4	41	8	74
Wet dust.	1949	2	38	0	62
	1950	3	51	7	81
Spray dusters, variously used.	1949	4	41	5	51
	1950	3	35	3	46
Unclassified.	1949	6	94	6	118
	1950	7	86	6	109
All farms.	1949	98	64	9	98
	1950	108	71	9	105
Hudson Valley.	1949	38	65	13	93
	1950	47	72	9	99
Western New York.	1949	60	63	7	100
	1950	61	71	8	110

¹⁰Kearl, C. D., and Ashe, A. J. Thirty-five years of cost accounts. Dept. Agr. Econ., Cornell Univ. A. E. 711:27-28. March 1950.



Equipment distribution	Figures below show number of farms in each equipment category as they are distributed in the above groups								
Dilute airblast	2	3	9	5	7	4	2		4
Concentrate airblast		2	3	2	2	1		2	3
High pressure with guns and/or brooms	2	8	10	3					
High pressure with masts or spray heads	2	2	6	4		3			
High pressure with various outlets		2	2						
Wet dust	1			2					
Spray dusters, variously used	1	1		1					
Unclassified		3	1		1			1	1

Figure 2. 108 orchards grouped by number of acres in bearing apples, 1950.

and its relationship to spray equipment used. The orchards varied in size from less than 20 to more than 220 acres of apple bearing trees. Almost two-thirds of all the orchards had between 20 and 80 acres of bearing apples. Eight growers had less than 20 acres; 31 growers had more than 80 acres of bearing apples.

As indicated in the table of figure 2, high pressure sprayers with guns and/or brooms were used on the smaller farms, high pressure rigs with masts on the small and medium-sized orchards, and both dilute and concentrate airblast equipment was found on farms of all sizes. Eleven of the 13 largest orchards had airblast equipment.

Block and tree characteristics affecting control practices and cost

Cultural practices and costs and yields of crop production are commonly compared on a per acre basis. When such comparisons are made for apple orchards, a number of variables must be studied simultaneously. Although the selected orchards were comparable in general, there were wide differences in various block and tree characteristics, as indicated in table 3.

Table 3. Number of trees per acre, tree size, and density in 116 survey blocks, 1950
(New York State)

Block and tree characteristics	Average	Lowest	Highest
Number of trees per acre.....	40	14	70
Age of trees.....	25	14	40
Estimated bearing capacity per tree	26	10	50
Tree height (in feet).....	19.8	13.0	24.7
Tree volume (in 1000 cubic feet)...	9.4	3.3	15.1
Density rating (index)*.....	2.7	1.7	4.0

*A rating of 1 was given to very open trees, a rating of 4 to very dense trees.

There were considerable differences in the number of trees per acre and in the size of trees between different machinery groups. As shown in table 4, the greatest number was in the high-pressure-with-masts group, though this was offset partly by the smaller bearing capacity of the trees. But to a large extent the effects of these ranges in physical conditions of the blocks and trees were averaged out in the different machinery groups. In terms of estimated bearing capacity, the Hudson Valley trees were somewhat larger than those in the western New York orchards.

Number of applications and gallonage

For the purpose of this study, coverage of trees from both sides was considered a single application. If only one tree side was covered, this was tabulated as one-half of an application. Averages of the number of applications and of the gallonage applied are shown in table 5. In 1950, the average number of applications for insect and disease control in 116 orchards was 12.4. The rates of applications were tabulated in number of gallons per acre, per tree, per thousand cubic feet of tree volume, and per bushel of bearing capacity. These rates were then expressed in quantities applied during the whole season, and in gallons per application.

Growers who contributed to this study used, on the average, slightly less

Table 4. Average block and tree characteristics in the survey, according to the different spray machinery classes and area (116 blocks of apples, New York State, 1950)

Type of equipment	Year	Blocks	Tree height	Tree volume	Density rating*	Estimated bearing capacity	Trees per acre
		Number	Feet	Thousand cubic feet	Index	Bushels	Number
Dilute airblast.....	1949	28	20	11.0		30	35
	1950	38	20	10.1	2.7	29	38
Concentrate airblast.....	1950	16	21	9.8	2.7	30	39
High pressure with guns and/or brooms	1949	36	21	9.6		28	38
	1950	23	19	8.8	2.7	26	38
High pressure with masts or spray heads	1949	20	20	8.4		27	47
	1950	20	20	8.4	2.6	27	47
High pressure with various outlets.....	1949	6	21	9.6		30	40
	1950	5	22	11.5	2.7	37	41
Wet dust.....	1949	2	19	5.8		18	46
	1950	4	17	5.1	2.9	16	41
Spray dusters, variously used.....	1949	4	20	8.3		21	45
	1950	3	20	10.2	2.8	30	45
Unclassified.....	1949	7	22	10.4		32	34
	1950	7	20	10.4	2.7	33	35
All blocks.....	1949	103	20	9.6		28	39
	1950	116	20	9.4	2.7	28	40
Hudson Valley.....	1949	38	22	10.1		32	39
	1950	52	21	9.4	2.6	30	40
Western New York.....	1949	65	19	9.3		26	39
	1950	64	19	9.4	2.8	27	40

*A rating of 1 was given to very open trees, a rating of 4 to very dense trees.

than half a gallon per bushel of bearing capacity for a single application. The number of applications and the gallons applied per acre indicated that in 1950 the Hudson Valley growers sprayed more often and applied larger quantities than in 1949. In both years the Hudson Valley orchards received more applications and larger quantities of spray than the orchards in western New York. These differences were at least partly the result of differences in problems with scab and rust. The range in number of applications and quantities applied was great; more than twice the average quantities were applied by some growers.

Table 6 shows that the number of gallons applied per acre did not depend on the type of dilute spray equipment used. Dilute airblast sprayers applied more than the average in 1949, less than the average in 1950. High pressure rigs with guns and brooms were below the average in 1949, but not in 1950. High pressure sprayers with mast equipment were slightly above average in both years.

Number of gallons of dilute spray applied per hour

The rate of spraying output may be expressed in terms of number of

Table 5. Number of applications and gallonage of spray for insect and disease control (116 blocks of apples, New York State, 1950)

	Year	Number of blocks	Number of applications	Number of gallons*			
				Per acre	Per tree	Per 1,000 cu. ft. of tree volume	Per bushel bearing capacity
	Whole season						
Hudson Valley.....	1949	38	12.7	5,296	157	16.9	4.85
	1950	52	14.0	5,557	159	17.0	4.99
Western New York...	1949	65	11.6	5,015	142	16.3	5.71
	1950	64	11.1	4,867	133	14.9	4.89
All blocks.....	1949	103	12.0	5,118	148	16.5	5.39
	1950	116	12.4	5,124	143	15.6	4.93
Range in 1950							
High.....			26.3	15,838	455	38.6	10.05
Low.....			7.0	2,165	51	8.2	2.32
	Per application						
Hudson Valley.....	1949	38	...	399	11.9	1.34	0.37
	1950	52	...	426	12.4	1.43	0.39
Western New York...	1949	65	...	414	11.8	1.36	0.47
	1950	64	...	465	12.8	1.33	0.48
All blocks.....	1949	103	...	408	11.8	1.35	0.43
	1950	116	...	450	12.6	1.40	0.44
Range in 1950							
High.....		..	...	1,108	27.1	3.06	1.00
Low.....		..	...	156	5.1	0.79	0.19

*Gallonage figures do not include concentrate or dust blocks. In a few orchards, one or more supplementary dust applications are not taken into account in this table.

gallons applied per hour. Data on the number of minutes spent for each application in the spraying operation, and on the total number of tanks sprayed on the survey block, were provided by the growers. These figures are the basis for the summaries shown in table 6.

The number of gallons applied per hour averaged highest for the blocks using dilute airblast equipment, and lowest for the blocks using high pressure sprayers with guns and brooms. The high-pressure-with-masts equipment was intermediate. The average output per hour was greater in 1950 than in 1949, and greater for growers in western New York than for growers in the Valley.

Time required for a single spray cycle

The time required for the various operations included in a round trip, or "cycle", of the sprayer was taken on most of the blocks. It included filling time, travel to the orchard, spraying, and travel back to the filling location. The results of these time and motion studies, expressed on the basis of 500 gallons of dilute spray, or its equivalent, are summarized in tables 7 and 8. Slightly less than two-thirds of the total cycle time was accounted for by gross spray time (table 7). The remainder of the total cycle time was spent in refilling the tank, and in traveling to and from the source of water. While this was true for the group as a whole, the operation of individual growers varied considerably.

Table 6. Gallonage of spray and speed of discharge
(With different types of dilute spray equipment; 96 blocks of apples in 1949,
90 blocks in 1950; New York State)

Type of equipment	Year	Number of blocks	Gallons per acre*	Gallons per hour*
Dilute airblast.....	1949	28	5,366	1,232
	1950	38	5,056	1,221
High pressure with guns and/or brooms.....	1949	36	4,449	609
	1950	23	5,451	718
High pressure with masts or spray heads.....	1949	20	5,981	776
	1950	20	5,370	929
High pressure with various outlets.....	1949	6	7,452	886
	1950	5	6,281	765
Unclassified.....	1949	6	2,757	528
	1950	4	5,064	823
All blocks.....	1949	96	5,118	838
	1950	90	5,300	985
Hudson Valley.....	1949	35	5,296	785
	1950	34	5,715	950
Western New York.....	1949	61	5,015	868
	1950	56	5,052	1,006

*Based on growers' day-to-day records. Data based on the timing of a single spray cycle yield a somewhat higher average output-per-hour, but are otherwise comparable to the data of table 7. Blocks sprayed with concentrates or dusts are not included.

Table 7. Time spent in spraying 500 gallons* of dilute spray, or its equivalent†
(With different types of equipment; 78 spray cycles in 1949, 84 cycles in 1950;
New York State)

Type of equipment	Year	Number of cycles	Filling time	Travel time	Gross spray time‡	Total cycle time
				Minutes		
Dilute airblast.....	1949	22	4.8	2.2	12.7	19.7
	1950	24	4.9	2.4	13.4	20.7
Concentrate airblast†.....	1950	13	4.8	2.8	24.7	32.3
High pressure with guns and/or brooms	1949	31	7.7	7.6	28.1	43.4
	1950	21	7.7	5.7	24.6	38.0
High pressure with masts or spray heads	1949	18	7.4	6.8	19.3	33.5
	1950	19	7.0	5.4	19.0	31.4
High pressure with various outlets.....	1949	5	5.9	8.5	24.8	39.2
	1950	4	6.1	7.7	21.8	35.6
Unclassified.....	1949	2	7.5	7.6	27.6	42.7
	1950	3	6.3	4.3	22.6	33.2
All blocks.....	1949	78	6.7	5.9	21.5	34.1
	1950	84	6.2	4.3	19.9	30.4

*Actual time converted to 500 gallon equivalent time for sprayers with tanks smaller or larger than 500 gallons.

†Concentrate spray converted to its dilute spray equivalent without taking into account any saving in materials that may have occurred.

‡Includes spray time—actual time required to spray out one tank of material, and nonspray time—time lost in such operations as turning at the ends of rows (spray shut off).

The average total cycle time for the dilute airblast operations was twenty minutes, about one-half the average time for high pressure sprayers using guns or brooms. The high pressure with mast and the concen-

trate operations were intermediate. In the case of the concentrate machines (see figure 3) two operations were extremely slow and accounted for most of the apparent increase in spray cycle time for the group. Since, as table 8 indicates, speed in the spray cycle of some dilute airblast and high pressure operations was associated with the use of transport rigs, the time involved in those operations needs to be considered. This will be done in connection with tables 9 and 10.

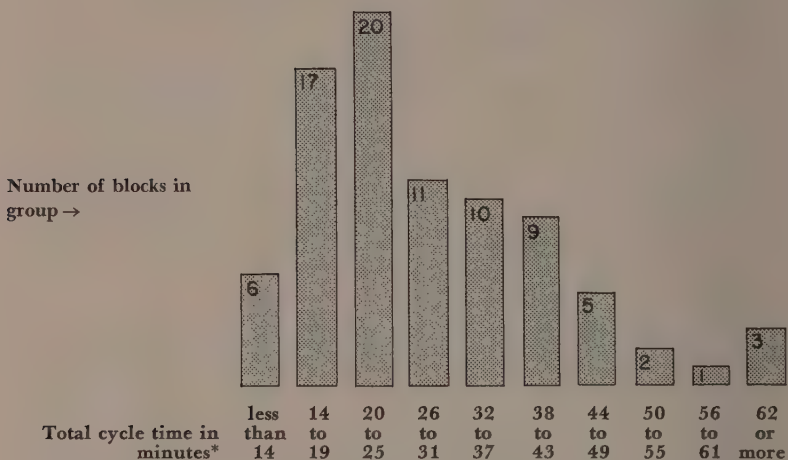
Figure 3 illustrates the wide range in total spray cycle time that existed within each machinery group in 1950. Three growers spent more than an hour per spray cycle, five times as long as the six most speedy operators. Two of the six in the group with the shortest spray time had dilute airblast, two had concentrate airblast rigs, and two broom equipment. These last two growers so far exceeded their group average because they had efficient discharge equipment; two men were spraying, each with a multi-nozzle broom. In addition, these growers cut their traveling and filling time by using water transport rigs.

The frequency distribution of figure 3 makes it clear that, with each kind of equipment studied, some growers achieved a high rate of output while others a low one. Table 8 groups the three main kinds of equipment according to their total cycle time into four time classes, on the basis of the two years of time and motion studies. Each type of equipment was represented in each of the four efficiency groups, with the exception of dilute airblast machines. None of these were in the slowest group. The striking point, however, is that on the average the fastest group was outstanding in all parts of the total spray cycle. It had the lowest gross spray time, the lowest non-spray time, the lowest filling time, and the lowest traveling time. Since transport rigs were used for 10 of the 27 operations

Table 8. Spray equipment grouped according to the number of minutes spent in spraying 500 gallons of dilute spray, or its equivalent*
(113 single spray cycles in 1949 and 1950, New York State)

Total cycle time	Type of equipment	Cycles	Transport rigs used	Total cycle time	Gross spray time	Filling time	Travel time
Minutes		Number	Number		Minutes		
Group I less than 21	Dilute airblast	17	6	16.7	10.6	4.5	1.6
	High pressure	6	4	17.3	12.1	4.5	0.7
	Concentrate airblast	4	0	17.4	13.5	2.4	1.5
Group II 21 to 32	Dilute airblast	13	1	24.7	16.1	5.1	3.5
	High pressure	14	2	25.6	15.8	6.2	3.6
	Concentrate airblast	7	0	25.4	18.6	5.1	1.7
Group III 32 to 45	Dilute airblast	2	0	35.8	21.6	8.2	6.0
	High pressure	26	0	38.7	24.0	7.4	7.3
	Concentrate airblast	2	0	39.1	29.7	6.2	3.2
Group IV 45 or more	Dilute airblast	0	..	..	..	..	..
	High pressure	20	2	56.0	35.9	10.3	9.8
	Concentrate airblast	2	0	98.5	77.5	10.5	10.5

*The conversion factor used for concentrate spraying time does not take into account possible savings in materials.



Equipment distribution	Figures below show number of blocks in each equipment category as they are distributed in the above time groups									
Dilute airblast	2	9	10	2	1					
Concentrate airblast† . . .	2	3	4	2					1	1
High pressure with guns and/or brooms	2		1	4	3	5	3	2		1
High pressure with masts or spray heads		5	4	1	4	3	1			1
High pressure with various outlets				2	1		1			
Unclassified			1		1	1				

*Includes time spent in filling, traveling, and actual spraying operation.

†Concentrate sprays converted to dilute spray equivalent on basis of concentration used.

Figure 3. 84 spray cycles grouped according to number of minutes spent on a complete spray cycle in 1950. Based on 500 gallons of dilute spray or its equivalent.

in this group, and since the time involved in the operation of the nurse rig was not included in the total time, the average speed of this group was increased at considerable expense.

Use of water transport trucks in relation to spray time

As table 9 shows, the use of a filler truck does not necessarily improve the efficiency of man labor in the overall spray operation. With few exceptions, the total number of man minutes per spray cycle increased when filler trucks were used.

Table 9. Man minutes per 500 gallon tank
(98 spray cycles, New York State, 1949 and 1950)

Type of equipment	Cycles	Total spray cycle time	Man time per sprayer cycle	Additional man time, due to use of filler truck	Total man time
	Number	Minutes			
Dilute airblast					
With filler truck.....	7	18.7	20.9	18.7	39.6
Without filler truck.....	19	20.7	25.2	...	25.2
Concentrate air blast					
Without filler truck.....	9	23.5	33.0	...	33.0
High pressure with guns and/or brooms					
With filler truck.....	5	47.4	66.6	47.4	114.0
Without filler truck.....	33	43.2	85.8	...	85.8
High pressure with mast or spray heads					
With filler truck.....	3	16.6	28.0	16.6	44.6
Without filler truck.....	22	33.6	47.4	...	47.4

Table 10 shows a general association between short travel time of the sprayer and the use of water transport trucks. Yet of the 29 operators with less than two minutes travel time there were 16 who did not use a transport rig. While this relationship existed, it seems plain that the use of transport rigs would not have decreased the sprayer's travel time in some operations if other provisions had been made for a ready water supply.

Table 10. Relationship between sprayer travel time and use of transport rigs in 113 operations, 1949 and 1950

Sprayer travel time	Operations observed	Operations using transport rigs	
Minutes	Number	Number	Per cent
Less than 2.....	29	13	44.8
2 to 4.....	24	4	16.7
4 to 8.....	34	1	2.9
More than 8.....	26	0	0

A grower should study his own situation to find out whether efficiency may best be promoted by the use of better and more conveniently located filling stations or by the use of a filler truck. In many instances the speed of covering an orchard may be enhanced by the use of a nurse rig. This may be profitable when the timing is particularly urgent, regardless of whether the number of man minutes would be increased or not. Table 11 analyzes in detail the time involved in use of nineteen nurse rig cycles.

Table 11. Average, and ranges of, time required for the cycle of 19 transport rigs, 1949 and 1950

	Travel time	Time to fill transport rig	Time to fill sprayer from transport	Total cycle time	Total, less filling of sprayer
			Minutes		
Average	4.64	5.66	6.55	16.85	10.30
Fastest...	1.22	2.70	2.62	8.72	6.10
Slowest..	14.63	11.30	25.00	47.83	22.83

spray cycle time (table 7). This means that waiting periods for the nurse rig and its operator occurred in many cases. Because of the complexities involved, it is not possible to assign an average cost or value to the use of a transport truck.

The following factors were found to be responsible for low actual spray time, from an engineering standpoint:

(1) The pump size was sufficiently large. All dilute sprayers in the top group of table 8 had a rated pump capacity of 50 gallons per minute, or more.

(2) The pump was used in such a manner that it approached its rated capacity. This was possible only where nozzles capable of discharging the pump capacity were provided.

To operate with a minimum of nonspray time while the sprayer was in the block, it had to be in good mechanical condition, with no time lost by nozzle clogging. The orchard layout, tree spacing, and the absence of skips also permitted maximum output per unit of time.

Filling time

Next to the gross spray time, most time was spent in refilling the tank with water and spray materials. Table 12 is concerned with filling time: the period when the water is actually running into the tank, and the additional time needed to complete the filling chores. Growers who had

Table 12. Filling operations grouped according to total time required to fill a 500-gallon tank (113 filling operations, New York State, 1949 and/or 1950)

Overall filling time	Operations	Time for filling tank with water	Additional time to complete filling chores	Overall filling time
Minutes	Number		Minutes	
Group I 4.5 and less	29	2.4	1.1	3.5
Group II 4.51 to 6	31	4.0	1.1	5.2
Group III 6.07 to 7.75	28	5.1	1.9	7.0
Group IV 7.8) or more	25	7.2	3.6	10.7

the most efficient water filling system needed very little additional time to complete the filling chores. Those in the fastest group had a water time of only 2.4 minutes. This gave them very little time to do the mixing and other filling chores, yet they completed the filling operation in an additional 1.1 minutes.

Conversely, growers in the slowest group, who filled

It should be noted that average total transport cycle time (table 11) was shorter than the average

their tanks in 7.2 minutes, needed another 3.6 minutes to complete the filling operation.

The water time was reduced by the use of overhead tanks or by the use of a pump of large capacity to fill the spray tank from a transport rig or other source of water. Where an overhead tank was available, it was most effective when the pipe and gate valve were three inches or more in diameter. The effect of the size of discharge valve is clearly shown in table 13. However, case studies revealed that some growers did not take full advantage of their high water filling rate, using more time than necessary for other filling chores; others had greater water filling rates than necessary for maximum speed of filling.

Ten of the 27 speediest operations used transport rigs for carrying water or mixed spray. Their speed was due to the fact that the transport operator helped in mixing and filling, and the mixed material was transferred to the spray tank without delay. Where tank fillers and small pumps were employed, their low capacity was found to be a limiting factor.

The travel time to and from the source of water depended on a number of factors:

- (1) The distance from the source of water, which varied with the number of filling points in the orchard and their accessibility.
- (2) The condition of the orchard roads and terrain.
- (3) The wheel and tire equipment of the tractor. In this study, many wheel-type tractors traveled more slowly than track-laying tractors, but the reason was not apparent.
- (4) Use of a transport rig, which in some cases reduced the travel time of the sprayer to zero.

Sources of water

The sources of water used by project growers in 1949 and 1950 are shown in table 14. The average capital invested in the various water supply systems was also tabulated according to the growers' estimates (table 15). Where supply rigs were used exclusively, the operation of the transport rig required additional labor and operating costs. A permanent water supply system involved little or no operating cost, and the capital invested could be depreciated over a long period.

Table 13. Relationship between size of discharge valve at overhead tank and time required for filling operation (500-gallon-equivalent basis*; 76 blocks of apples, New York State, 1949 and 1950)

Size of discharge valve at overhead tank	Number of blocks	Rate of filling tank with water	Water time	Filling time
Inches		Gallons per minute	Minutes	
4.....	6	197	2.5	4.1
3.....	11	164	3.1	4.9
2½.....	12	123	4.1	5.5
2.....	30	97	5.2	7.5
1½.....	2	94	5.3	6.1
Tank filler equipment.	15	96	5.2	7.9

*Concentrate spray converted to dilute spray equivalent.

†Concentrate spray not converted for rate of filling, and therefore not included in this average.

Sources of Water . . .



Figure 4. Overhead tanks with gravity flow through large discharge pipe.

Figure 5. Artificial pond dug by fruit grower.



. . . Methods of Filling the Sprayer



Figure 6. Tank refiller powered by sprayer pump.

Figure 7. Mechanized transport rig on which centrifugal pump draws water from pond or well and transfers it to sprayer.



Table 14. Sources of water for spraying apples
(138 sources in 98 orchards in 1949; 177 sources in 108 orchards in 1950; New York State)

Source of water	Number of sources		Per cent	
	1949	1950	1949	1950
Water-hole or pond	46	72	33.3	40.8
Stream or creek	33	30	23.9	17.0
Well	20	37	14.5	20.9
Spring	17	10	12.3	5.6
Village water supply	12	10	8.7	5.6
Lake	7	8	5.1	4.5
Other	3	10	2.2	5.6
Total	138	177	100	100

Table 15. Average investment in different types of water supply systems
(102 farms in 1949, 103 farms in 1950, New York State)

Predominant water supply system used on farm	Year	Number of farms	Total investment per farm*
			Dollars
Overhead tank, pump and motor—1 system	1949	36	313
	1950	32	323
Overhead tank, pump and motor—2 systems	1949	16	672
	1950	19	638
Overhead tank, pump and motor—3 or more systems	1949	3	1,078
	1950	8	1,300
Gravity feed	1949	9	211
	1950	7	371
Pump and motor—no overhead tank	1949	7	117
	1950	20	379
Water supply rig only	1949	8	412
	1950	7	523
Tank filler	1949	23	24
	1950	10	51
All blocks	1949	102	285
	1950	103	458

*Valued at cost minus depreciation or at grower's estimate of present value.

Discussion

On these rather large, specialized fruit farms, dilute airblast sprayers discharged the spray fastest, regular sprayers equipped with masts or spray heads came next, and high pressure rigs with guns or brooms were slowest. The rates of discharge of concentrate rigs can be compared only in a general way, because 100 gallons of spray covers several times as many trees. When converted to a dilute spray equivalent, the gallonage discharged by concentrate sprayers seemed similar, on the average, to that of the high pressure sprayers equipped with masts. Data presented later (table 22) suggest that some mast sprayers and some dilute airblast rigs discharging spray most rapidly were not doing a good job of covering the foliage. Some of the greatest opportunities for speeding up the

coverage of the orchard are in the use of transport rigs, or in improvement of the locations and set-ups of the filling stations. Tables 9–13 give hints as to how this can be done. With high pressure sprayers using guns or brooms, rapid output was promoted by providing nozzles that utilized a maximum proportion of the discharge capacity of the pump.

Physical Relationships and Their Effects on Pest Control

The injuries to fruit at the end of the summer caused by apple scab and by three major insect pests — plum curculio, red-banded leaf roller, and codling moth — were counted on sample trees in each orchard. Counts of leaf scab were also made in both years. The pest control data were

grouped according to the spray equipment used, gallons, number and timing of sprays, tree height and density, in an effort to discover dominant relationships between these measurements and pest control.¹¹

Weather and pest control

The weather conditions in 1949 were very different from those in 1950, and had a very marked influence on insect and disease problems. In the 1949 growing season, rainfall was low, and both temperature and light were high. In the 1950 growing season, rainfall was above average and well distributed, and both temperature and light were below average. The early, warm, dry season of 1949 was followed by some restriction of growth, an early harvest, and a heavy bloom for 1950. It also made scab control less difficult and codling moth control more difficult than usual. The late, cool, moist season of 1950 resulted in rather vegetative growth and a late harvest. It also made scab more of a problem and codling moth less of a problem than usual. These findings are shown, in table 16, for

Table 16. Comparison between control of apple scab, codling moth, and plum curculio in 63 McIntosh orchards surveyed

Average determinations	Total		Western New York		Hudson Valley	
	63 orchards		36 orchards		27 orchards	
	1949	1950	1949	1950	1949	1950
	Per cent					
Spur leaf scab*.....	1.4	4.4	2.1	4.9	0.4	3.7
Terminal leaf scab*	4.2	5.9	5.1	6.0	3.2	5.8
Injuries per hundred fruit†						
Fruit scab.....	4.5	12.9	6.7	14.3	1.5	11.1
Codling moth.....	7.7	2.4	8.8	3.5	6.3	1.0
Plum curculio.....	1.9	6.3	0.9	5.3	3.3	7.7
Picked clean fruit	88.0	82.3	85.9	81.0	90.7	84.1

*Percentage of early leaf scab is based on a count made in June on the primary rosette of spur leaves; percentage of terminal leaf scab is based on a count in midsummer on leaves of terminals.

†From harvest samples taken from all portions of tree, not including drops. Figures are for injuries per 100 fruits in the case of these insects.

a little better scab control, on the average, than did western New York co-operators. This was at the expense of an average of about 12½ fungicide applications, as compared with an average of 10 in the western New York blocks.

Type of spray equipment and pest control

In both years the average pest control on blocks sprayed with dilute airblast machines was somewhat better than the average on all blocks. Blocks sprayed with high pressure machines with guns and brooms were a little below average in pest control in 1949, but better than average in

¹¹All of the data on fruit injuries are confined to these four pests. This means that injuries from other insects and diseases were not counted even if they were major pests in a particular orchard.

1950. The blocks sprayed with high pressure machines having mast equipment were close to the average in both these seasons. The average insect control for blocks sprayed with concentrate airblast machines in 1950 was close to the general average, but scab control was below average, perhaps partly as a result of having inexperienced operators. It may also be that scab control offered a more critical test of the coverage ability of the machines in 1950, since the average percentage of fruits with scab exceeded the sum of injuries caused by the three insects studied. This relative importance of scab in 1950 is greater than immediately apparent from table 17, since multiple injuries on the same fruit were counted for codling moth and for curculio, but not for scab. For instance, two codling moth stings on one of a hundred apples were counted as two insect injuries per hundred fruit. Conversely, ten scab lesions on one of a hundred apples were recorded as only 1 per cent fruit injured by scab. The averages of the other equipment groups were not based on enough observations to be dependable.

Table 17. Relationship between type of equipment used and overall control of scab and insect pests

(103 selected blocks of apples in 1949; 116 blocks in 1950, New York State)

Type of equipment	Year	Blocks	Picked fruit with scab	Insect injuries per 100 picked apples*	Picked fruit injured†
		Number	Per cent	Number	Per cent
Dilute airblast.....	1949	28	1.9	7.9	7.2
	1950	38	7.6	10.7	13.8
Concentrate airblast.....	1950	16	18.3	11.0	23.9
High pressure with guns and/or brooms	1949	36	4.7	14.2	14.5
	1950	23	7.2	11.8	15.1
High pressure with masts or spray heads	1949	20	6.6	8.8	12.8
	1950	20	11.9	9.7	17.0
High pressure with various outlets.....	1949	6	3.1	7.5	9.3
	1950	5	11.3	9.3	16.6
Wet dust.....	1949	2	4.9	9.0	10.2
	1950	4	34.2	13.4	39.4
Spray dusters, variously used.....	1949	4	27.3	23.3	38.9
	1950	3	12.1	7.5	16.0
Unclassified.....	1949	7	10.6	12.9	20.5
	1950	7	12.8	14.1	20.7
All blocks.....	1949	103	5.4	11.2	13.0
	1950	116	11.2	10.9	17.5
Hudson Valley.....	1949	38	3.1	13.2	12.0
	1950	52	11.7	11.2	17.8
Western New York.....	1949	65	6.8	9.9	13.2
	1950	64	10.9	10.8	17.2

*Includes injuries from curculio, red-banded leaf roller, and codling moth.

†This figure is less than the sum of the two preceding columns because sometimes one apple had several injuries.

The presentation of averages does not, of course, convey the complete picture. An average of 18 per cent of fruit was injured by the four pests considered in all the 1950 project orchards. Yet, as tables 17, 18 and figure 24 show, individual orchards varied greatly in control: the best had 99 per cent, the poorest 38 per cent, of picked clean fruit. Seventy growers were in the best four groups, with more than 85 per cent of clean fruit. Nine growers had less than 50 per cent of clean fruit. In all the major equipment categories the range of clean fruit was from less than 50 per cent to more than 95 per cent. All such figures are only relative, since injuries caused by several insect pests and by spray were not recorded.

Table 18. Relationship between the type of equipment used and injuries per 100 apples by individual insect pests
(98 selected blocks of apples in 1949, 116 blocks in 1950, New York State)

Type of equipment used	Year	Number of blocks	Insect injuries per 100 picked apples			
			Curculio	Red-banded leaf roller*	Codling moth	All insects
Dilute airblast.....	1949	28	1.2	1.1	5.6	7.9
	1950	38	7.0	1.7	2.0	10.7
Concentrate airblast.....	1950	16	6.5	0.7	3.8	11.0
High pressure with guns and/or brooms	1949	33	2.5	3.3	7.8	13.6
	1950	23	7.5	2.8	1.6	11.8
High pressure with masts or spray heads	1949	20	1.6	2.2	5.0	8.8
	1950	20	5.7	1.3	2.7	9.7
High pressure with various outlets.....	1949	6	0.7	2.5	4.3	7.5
	1950	5	7.9	0.4	1.0	9.3
Wet dust.....	1949	2	7.0	0.2	1.8	9.0
	1950	4	9.8	0.6	2.9	13.4
Spray dusters, variously used.....	1949	4	7.6	6.1	9.3	23.0
	1950	3	5.8	0.1	1.5	7.5
Unclassified.....	1949	5	1.4	4.6	8.5	14.5
	1950	7	9.4	0.7	4.0	14.1
All blocks.....	1949	98	2.1	2.6	6.4	11.1
	1950	116	7.0	1.5	2.4	10.9
Hudson Valley.....	1949	37	4.8	2.1	6.5	13.4
	1950	52	8.7	0.5	1.9	11.2
Western New York.....	1949	61	0.5	2.8	6.3	9.6
	1950	64	5.7	2.4	2.7	10.8

*No multiple injuries were reported for red-banded leaf roller.

Tree height, foliage density, and pest control

Table 19 shows the relationship between tree height and the relative proportion of injured fruit in the tops of the trees, as compared with the injured fruit on lower branches, for 92 blocks in 1950. For total injuries from the three insects and scab, the ratio of injuries at the top to injuries at the bottom increased with each increment in tree height. For the injuries by each of these pests separately the ratio of injuries did not con-

High Pressure Sprayers with Guns and/or Brooms



Figure 8. Spraying from ground with single gun and long hose.

Figure 9. Two men spraying with single guns from low and high positions on rig.



High Pressure Sprayers with Guns and/or Brooms



Figure 10. Tractor driver operating one gun and another man spraying from top of tank.

Figure 11. Spraying with 8-nozzle broom from top of tank.

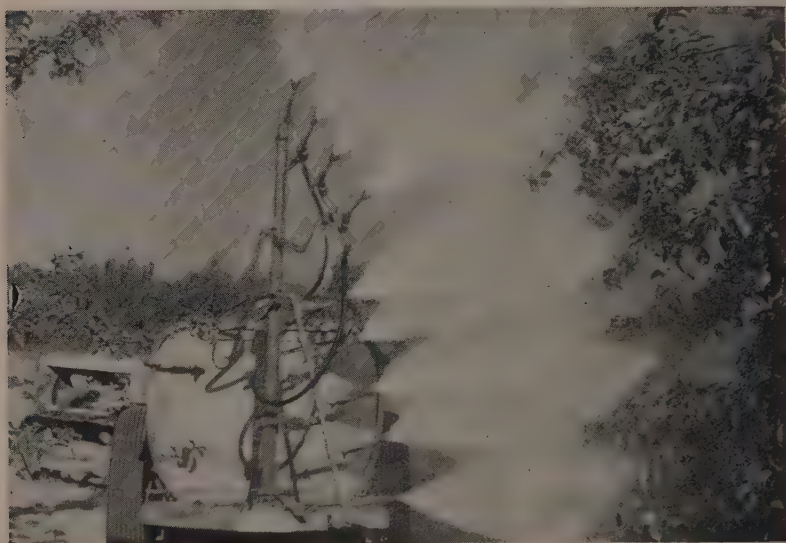


High Pressure Sprayers with Masts or Spray Heads



Figure 12. Oscillating Iron Age spray head (not discharging) plus under-tree boom.

Figure 13. Low mast with adjustable single guns.



High Pressure Sprayers with Masts or Spray Heads

Figure 14. High mast with adjustable single guns.



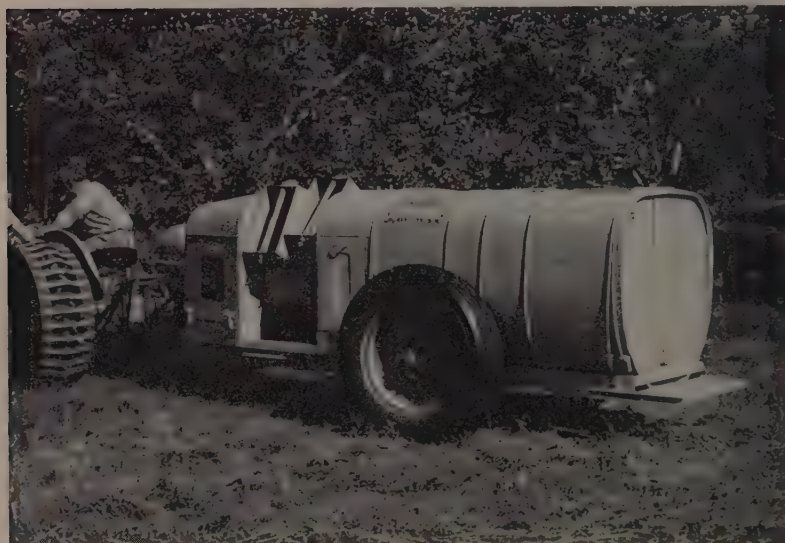
Figure 15. Oscillating Traverse City boom with fixed-pattern nozzles at three levels.

Airblast Sprayers for Dilute Mixtures



Figure 16. Bean Speed Sprayer operating one side.

Figure 17. Myers airblast sprayer with oscillating heads.



Airblast Sprayers for Dilute Mixtures

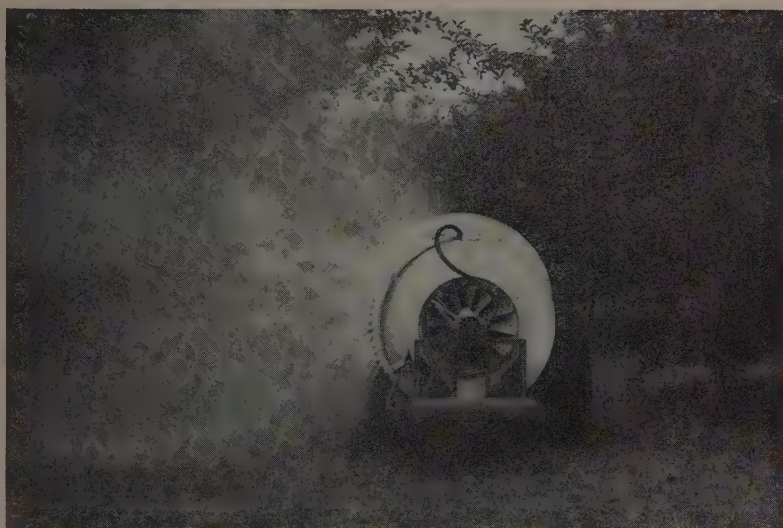


Figure 18. Rear view of Friend airblast sprayer.

Figure 19. Hardie Air Queen. (All four types of airblast sprayers shown on these two pages can be converted for use with moderately concentrated mixtures.)



Airblast Sprayers for Concentrate Mixtures



Figure 20. Hardie concentrate sprayer.

Figure 21. Lawrence Mistomatic concentrate sprayer with three rotating outlets.



Airblast Sprayers for Concentrate Mixtures



Figure 22. Buffalo Turbine, orchard model; will apply concentrate spray, dry dust, or wet dust.

Figure 23. Niagara Liquid Duster; will apply concentrate spray, dry dust, or wet dust.



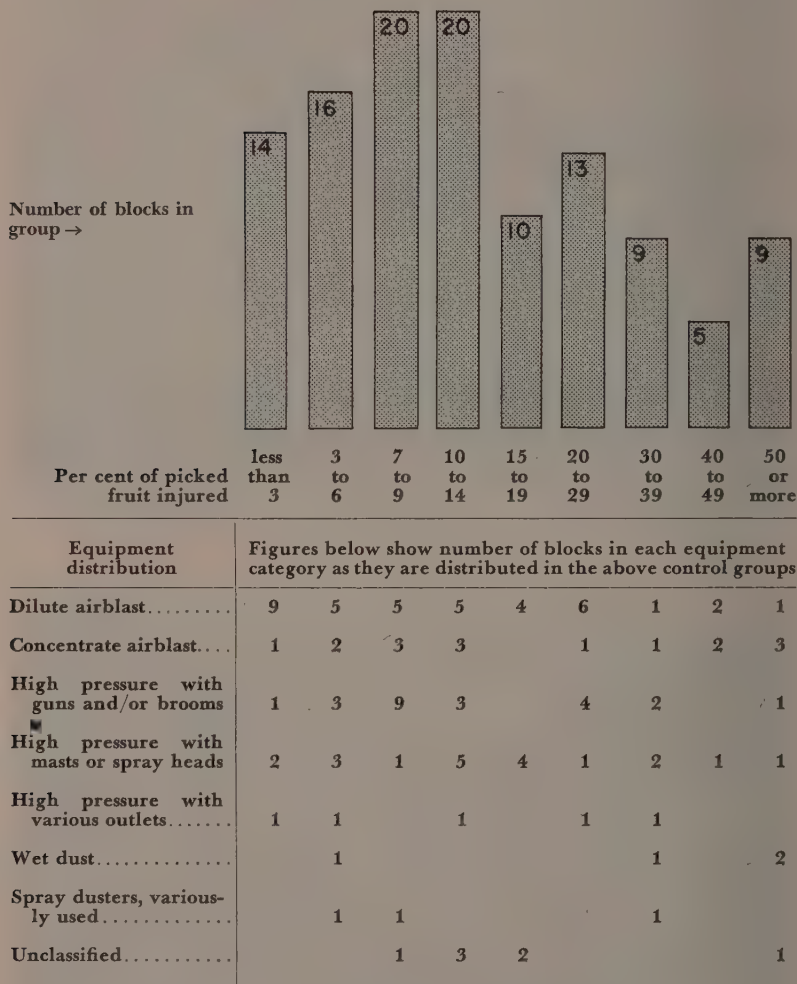


Figure 24. 116 blocks of apples grouped according to percentage of picked fruit injured in 1950.

Table 19. Relationship between tree height and ratio of injuries per 100 picked fruit at top to fruit injuries in lower part of tree*
(92 blocks of apples in 1950, New York State)

Tree height	Number of blocks	Codling moth	Red-banded leaf roller	Plum curculio	Apple scab	All pests
Feet						
13-16	15	2.14	1.70	2.20	1.49	1.71
17-19	34	3.39	1.26	2.04	2.18	2.16
20-21	24	3.20	3.39	3.09	2.66	2.92
22-25	19	4.30	3.85	4.60	3.11	3.57

*A ratio of 1 would mean that there were as many injuries per 100 fruits in the sample from the lower part of the tree as in the sample from the upper part of the tree.

sistently increase with each increment in tree height, but the trends were obvious. Although a little less spray and fewer pounds of toxicants were applied to small trees than to larger ones, as shown in table 20, tree height was clearly a factor limiting effective pest control. It is noteworthy, however, that the gallonage per bushel of bearing capacity decreased with increasing bearing capacity. There may be serious question as to whether the average amount of spray applied to the larger trees was adequate for thorough coverage.

Eighty-nine orchards in 1950 were rated for density of foliage. A rating of one was given to very open trees; trees with extremely dense foliage were rated as four. When these orchards were grouped according to their density rating, most of them (74) fell in the intermediate group; this indicates that moderate pruning was practiced in most blocks. In only seven blocks were the trees very dense, and in only seven others were they extremely open. Table 21 shows that pest control was poorest on the trees with very dense foliage. Slightly better control was observed on very open trees.

Table 20. Rates of spray and quantities of insecticide applied to trees of different sizes*
(92 blocks of apples, New York State, 1950)

Tree height	Blocks	Bearing capacity	Spray per tree per application	Insecticide toxicants per tree*	Bearing capacity per application
Feet	Number	Bushels	Gallons	Pounds	Gal. per bu.
13-17	15	19.8	9.9	1.44	0.50
17-20	34	25.4	12.4	1.59	0.49
20-22	24	30.7	14.1	1.77	0.46
22-25	19	32.8	12.8	1.87	0.39

*Includes insecticides but no miticides, on the basis of actual toxicant in the material used.

Table 21. Relationship between foliage density and pest control
(88 blocks of apples, New York State, 1950)

Density rating*	Number of blocks	Injuries per 100 fruit
1.7-2.3.....	7	17.7
2.4-3.2.....	74	22.0
3.3-4.0.....	7	35.9

*A density rating of 1 is for very open trees; 4 is for exceedingly dense trees.

Gallons per hour and pest control

The number of gallons applied per hour by different machines has been

discussed under *Physical Relationships* (page 13) as a measure of spray efficiency. Table 22 relates the rate of application to pest control in the three largest machinery categories. For one type of equipment (high pressure with guns and/or brooms), average control improved fairly consistently with the number of gallons applied per hour. For the high-pressure-with-masts group, and the dilute-airblast group, there was no improvement in control, and some tendency for control to be less satisfactory as the rate of application rose beyond about 1200 gallons per hour. There were, however, very few blocks involved in the averages for the highest rates of discharge.

In a study made in 41 western New York orchards in 1946, K. L. Robinson found that pest control was best in orchards with the most rapid rate of application.¹² As shown in table 23, the figures he observed ranged

Table 22. Relation of number of gallons applied per hour to insect and disease control (With different types of equipment; 84 blocks of apples in 1949, 81 blocks in 1950; New York State)

Type of equipment	Number of gallons per hour*	Number of blocks	Number of injuries per 100 picked apples		Per cent of picked fruit injured
			Scab†	Insect†	
1950					
Dilute airblast.	200-499	1	6.1	25.8	20.5
	700-899	5	11.5	11.5	17.5
	900-1,099	9	4.8	16.3	13.3
	1,100-1,299	10	4.5	6.6	9.2
	1,300-1,499	4	14.3	5.1	16.2
	1,500 or more	9	8.9	10.1	15.6
High pressure with guns and/or brooms. .	200-499	4	5.8	29.0	22.0
	500-699	10	9.6	9.0	17.0
	700-899	6	5.6	9.3	11.8
	900-1,099	1	9.7	5.9	14.2
	1,300-1,499	1	0.8	1.6	1.4
	1,500 or more	1	1.1	2.3	3.2
High pressure with masts or spray heads	200-499	4	9.4	9.8	14.3
	500-699	3	19.1	8.5	21.7
	700-899	3	14.2	10.5	19.3
	900-1,099	4	3.4	8.4	8.9
	1,100-1,299	1	7.9	11.2	14.1
	1,300-1,499	3	9.6	13.4	17.8
	1,500 or more	2	25.2	6.1	28.0
1949					
Dilute airblast.	900-1,099	8	1.1	8.6	6.7
	1,100-1,299	11	1.8	5.8	6.3
	1,300-1,499	5	2.2	5.1	6.1
	1,500 or more	4	3.2	15.6	11.6
High pressure with guns and/or brooms. .	200-499	7	11.8	20.1	24.9
	500-699	19	3.5	15.7	14.4
	700-899	8	2.1	9.1	8.8
	900-1,099	2	0.1	1.9	1.5
High pressure with masts or spray heads. .	200-499	3	3.1	7.8	9.3
	500-699	7	2.9	10.7	10.4
	700-899	3	20.6	13.3	28.2
	900-1,099	5	3.7	4.8	7.8
	1,100-1,299	2	10.5	7.0	15.6

*Based on agricultural economics data.

†No multiple injuries reported for scab or red-banded leaf roller.

¹²Robinson, K. L. Cost and efficiency in spraying apples, 1947, p. 112. Thesis for degree of M.S., Cornell Univ. (Unpublished.) 1947.

from less than 400 to more than 800 gallons per hour. In 1950 and 1949, some growers sprayed more than 1500 gallons per hour. This suggests that, in the upper ranges of output for modern equipment, the rate of travel associated with high rates of discharge may be increased beyond a practical speed for thorough coverage.

Table 23. Relation of the number of gallons applied per hour to insect and disease control (41 fruit farms sprayed with high pressure equipment, New York State, 1946)

Gallons applied per hour (time record)	Num-ber of records	Type of injury		
		Scab	Codling moth	Total
Per cent of fruit injured				
Less than 400.....	2	17	16	33
400 to 600.....	11	15	12	27
600 to 800.....	14	14	4	18
800 or more.....	14	10	2	12
Total or average	41	13	6	19

Fungicidal, insecticidal, and hormone materials

Each spray application recorded was labeled as fungicidal, insecticidal, or hormone. If both fungicide and insecticide materials were used, the application was counted as both fungicidal and insecticidal. Hormones were applied by 62 growers at preharvest time; hormone thinning was used in five orchards (table 24).

Table 24. Average number of applications in which fungicide, insecticide, or hormone materials were included

(With different types of equipment; 103 blocks in 1949, 116 blocks in 1950; New York State)

Type of equipment	Year	Number of blocks	Average number of applications			
			Fungicide	Insecticide	Hormone	Total
Dilute airblast.....	1949	28	9.9	8.7	0.5	13.0
	1950	38	10.8	7.6	0.6	12.9
Concentrate airblast.....	1950	16	11.6	7.5	0.6	13.3
High pressure with guns and/or brooms	1949	36	8.9	7.8	0.7	12.0
	1950	23	10.0	7.9	0.6	12.3
High pressure with masts or spray heads	1949	20	10.6	8.2	0.7	13.0
	1950	20	10.6	7.4	0.5	12.3
High pressure with various outlets.....	1949	6	9.2	9.2	0.7	13.1
	1950	5	11.2	7.7	0.9	13.2
Wet dust.....	1949	2	9.5	7.5	0.5	12.5
	1950	4	13.1	7.9	0.1	14.2
Spray dusters, variously used.....	1949	4	10.6	9.0	0.9	13.8
	1950	3	16.3	8.8	0.1	18.8
Unclassified.....	1949	7	8.5	8.2	0.4	11.7
	1950	7	11.9	7.7	0.4	13.7
All blocks.....	1949	103	9.5	8.3	0.6	12.6
	1950	116	11.0	7.7	0.6	13.0
Hudson Valley.....	1949	38	9.6	8.9	0.9	13.5
	1950	52	12.6	8.7	0.5	14.6
Western New York.....	1949	65	9.5	7.9	0.5	12.1
	1950	64	9.8	6.8	0.6	11.7
Per cent of total applications.....	1949	..	75	66	5	100
	1950	..	85	59	5	100

With the exception of the three spray-duster operations, the number of sprays did not vary with equipment used. For all blocks, an average of 13 applications were made in 1950, a figure slightly larger than in 1949. Fungicides were included in 75 per cent of the total in 1949, and in 85 per cent of all the applications in 1950. Insecticides were included in 66 per cent in 1949, and in 59 per cent in 1950. Hormone sprays accounted for 5 per cent both years.

For both years a larger number of applications were made, on the average, in the Hudson Valley orchards than in the western New York ones. According to the number of fungicidal applications, the 1950 season appeared to have been more difficult in the control of scab, particularly in the Hudson Valley.

Total number of applications and pest control

For 1950, the orchards were grouped according to the total number of applications for insect and disease control. As table 25 indicates, little relationship between number of applications and pest control could be observed for orchards in the Hudson Valley. Control did not improve with an increasing number of applications. The orchards in western New York showed poorer control of scab with an increasing number of applications, and no trend for insect injuries. For all blocks together, the overall control in terms of picked, clean fruit declined with an increasing number of applications. The greater number of sprays given orchards with inferior scab control appeared to be the result of attempts by growers to check damage after scab or insect injuries were present in the trees.

Table 25. Relation of the number of applications for pest control to injuries on fruit (116 blocks of apples, New York State, 1950)

Number of applications	Number of blocks	Number of injuries per 100 picked apples		Per cent of picked fruit injured
		Scab*	Insect†	
Hudson Valley				
9.5-11.4.....	6	8.9	16.9	17.9
11.5-13.4.....	14	10.4	9.8	16.2
13.5-15.4.....	18	8.0	7.2	12.7
15.5 or more.....	14	19.0	15.2	25.9
Western New York				
Less than 9.5.....	9	4.3	10.5	11.6
9.5-11.4.....	29	5.4	12.1	12.8
11.5-13.4.....	18	17.6	8.2	21.9
13.5-15.4.....	6	21.2	10.4	26.8
15.5 or more.....	2	28.0	16.6	35.8
All blocks				
Less than 9.5.....	9	4.3	10.5	11.6
9.5-11.4.....	35	6.0	12.9	13.6
11.5-13.4.....	32	14.5	8.9	19.4
13.5-15.4.....	24	11.3	8.0	16.2
15.5 or more.....	16	20.1	15.4	27.1

*Multiple injuries were not reported for scab or red-banded leaf roller.

†Included injuries from curculio, red-banded leaf roller, and codling moth.

Gallons per unit of tree volume and pest control

The number of gallons applied per acre, per tree, per bushel of estimated bearing capacity, and per thousand cubic feet of tree volume was tabulated for both years studied. The best rate of application cannot be

adequately determined by any single measure listed above, for the spray requirement per acre depends on the number of trees and on their size. Table 26 makes use of the number of gallons per thousand cubic feet of volume because it may be superior in eliminating such variables as number of trees per acre or tree size. The tabulations based on other units of measurement were not, for want of space, included here.

No simple relationship could be observed for all the blocks between the number of gallons per thousand cubic feet of volume and pest control.

While there was an apparent decrease in scab infection associated with increasing gallonage for the Hudson Valley blocks, it was not evident in the western New York blocks. Furthermore, the first group in the Hudson Valley with the poorest scab control is based on only one case.

Number of fungicidal applications and scab control

In general, more fruit scab was found on the blocks that received the greater number of fungicide sprays (table 27). This appeared to have resulted where scab was not permitted to get established on the spur leaves, and, consequently, fewer sprays were needed for control of secondary infections. Where spur leaves became heavily infected, losses from fruit scab were serious, despite numerous summer sprays.

Table 26. Relation of quantity of spray applied to pest control
(86 blocks of apples, New York State, 1950)

Gallons per 1000 cubic feet (whole season)	Number of blocks	Number of injuries per 100 picked apples		Per cent of picked fruit injured
		Scab*	Insect†	
Hudson Valley				
Less than 10.....	1	28.3	8.8	31.0
10-12.9.....	9	14.9	10.7	19.5
13-15.9.....	7	15.0	12.5	22.6
16-18.9.....	6	9.2	14.3	16.6
19-21.9.....	4	6.8	11.9	16.4
22 or more.....	5	1.7	10.0	7.8
Western New York				
Less than 10.....	7	5.2	9.8	11.4
10-12.9.....	18	6.1	13.9	15.1
13-15.9.....	12	9.0	8.2	13.8
16-18.9.....	8	7.5	8.3	12.8
19-21.9.....	4	3.0	4.8	6.2
22 or more.....	5	13.2	9.6	17.6
All blocks				
Less than 10.....	8	8.1	9.7	13.8
10-12.9.....	27	9.0	12.8	16.6
13-15.9.....	19	11.2	9.8	17.0
16-18.9.....	14	8.2	10.9	14.4
19-21.9.....	8	4.9	8.3	11.3
22 or more.....	10	7.5	9.8	12.7

*Multiple injuries were not reported for scab or for red-banded leaf roller.

†Includes injuries from curculio, red-banded leaf roller, and codling moth.

Table 27. Relation between total number of fungicidal applications and scab control
(116 blocks of apples, New York State, 1950)

Number of fungicidal applications	Number of blocks	Spur leaves scabby	Terminal leaves scabby	Picked apples with any scab
Hudson Valley			Per cent	
7.5-9.4.....	5	1.0	2.9	3.5
9.5-11.4.....	11	2.9	8.7	13.0
11.5-13.4.....	16	1.6	2.3	9.1
13.5-15.4.....	14	1.4	6.8	8.2
15.5 or more.....	6	14.9	7.0	31.4
Western New York				
Less than 7.5....	8	1.6	2.5	4.7
7.5-9.4.....	17	0.8	1.1	3.7
9.5-11.4.....	26	3.9	4.9	11.9
11.5-13.4.....	10	9.2	7.5	16.8
13.5-15.4.....	3	14.4	12.1	39.5
All blocks				
Less than 7.5....	8	1.6	2.5	4.7
7.5-9.4.....	22	0.9	1.5	3.6
9.5-11.4.....	37	3.6	6.1	12.2
11.5-13.4.....	26	4.5	4.3	12.1
13.5-15.4.....	17	3.7	7.7	13.7
15.5 or more.....	6	14.9	7.0	31.4

Number of insecticidal applications and insect control

No simple relationship was evident between the number of insecticidal applications and total insect injuries, as shown in table 28. However,

Table 28. Effect of number of insecticidal applications on insect pest control
(116 blocks of apples, New York State, 1950)

Number of insecticidal applications	Number of blocks	Insect injuries per 100 picked apples			
		Cur-culio	Red-banded leaf roller*	Cod-ling moth	Total insect injuries
Hudson Valley					
Less than 7.....	3	8.8	1.5	3.3	13.6
7-7.9.....	11	9.5	0.6	2.2	12.3
8-8.9.....	13	8.9	0.4	1.8	11.1
9 or more.....	25	8.3	0.4	1.7	10.4
Western New York					
Less than 7.....	26	5.1	3.0	3.3	11.4
7-7.9.....	21	7.1	2.5	2.7	12.3
8-8.9.....	15	4.8	1.2	2.0	8.0
9 or more.....	2	4.9	1.5	0.9	7.3
All blocks					
Less than 7.....	29	5.5	2.8	3.3	11.6
7-7.9.....	32	7.9	1.9	2.5	12.3
8-8.9.....	28	6.7	0.8	1.9	9.4
9 or more.....	27	8.0	0.5	1.7	10.2

*No multiple injuries were reported for red-banded leaf roller.

when the injuries caused by the individual insects were analyzed, a trend could be observed for decrease in injury from codling moth and red-banded leaf roller as the number of insecticidal applications increased. The third, curculio injury, did not seem to be related to the number of applications; this insect is controlled by one, two, or three sprays only, which must be accurately timed during the short period when the adults are active.

Appropriateness of timing and amount of fungicides

For both seasons studied, the orchards were rated as to the appropriateness of the timing of scab sprays during the primary infection period (table 29). The rating was based on detailed

Table 29. Relation of appropriateness of timing during primary infection period to amount of fungicides applied
(97 blocks of apples in 1949; 111 blocks in 1950; New York State)

Orchards rated as to timing of scab sprays	Number of blocks	Gallons of fungicidal spray		Per cent of total crop with fruit scab
		Per acre, whole season	Per 1000 cu. ft. of volume, whole season	
		1949		
Excellent...	14	4,079	12.0	10.2
Good.....	48	3,725	12.8	13.2
Fair.....	30	4,691	14.7	14.6
Poor.....	5	5,067	15.4	13.7
		1950		
Excellent...	22	4,023	11.8	7.5
Good.....	37	4,132	11.9	7.0
Fair.....	34	5,012	15.5	20.0
Poor.....	18	5,210	16.5	7.1

records of weather and biological conditions. In judging the timing, full consideration was given to the fact that what is good timing for an eradicator may be poor timing for a protectant. The timing of each application was scored according to the specific fungicide used. While certain limitations are inherent in this rating because of local differences in climatic conditions, the data emphasize the importance of appropriate timing.

More gallons were ap-

plied per acre and per thousand cubic feet of volume by growers whose timing was rated fair or poor than by those with good or excellent timing. It is more economical to time early-season sprays properly with reference to infection periods than to apply greater quantities of spray.

Mercury fungicides and scab control

The advantages and disadvantages of mercury materials as compared with other fungicides have been debated during recent years. Sulphur materials are still the most widely used. Some of the new fungicides, such as the mercury materials, are used primarily because, when applied promptly after a scab rain, they prevent the appearance of new scab spots. They also are somewhat effective in eradicating very young scab spots and may cause dropping of heavily scab infected leaves. The phenyl mercury materials were used in 1950

by 53 growers, 72 per cent of whom were in the Hudson Valley. Control figures for fruit and leaf scab (table 30) showed that growers who used no mercury fungicides obtained as good control as did growers who used these fungicides. Some who used four or more mercury sprays were probably trying to check a serious outbreak on early leaves. The effects of mercury fungicides on cost is discussed in a later section.

Table 30. Relation between number of mercury applications and scab control
(116 blocks of apples, New York State, 1950)

Number of mercury applications	Number of blocks	Leaf scab		Fruit scab	
		Per cent spur leaves scabby	Per cent terminal leaves scabby	Per cent picked fruit with scab	Per cent combined picked and drops with scab
Hudson Valley					
Less than 1	17	2.3	6.0	12.9	13.0
1 to 3.9	23	3.0	5.8	9.0	12.6
4 and over	12	5.3	4.1	15.2	16.2
Western New York					
Less than 1	52	4.2	4.4	9.8	10.6
1 to 3.9	12	4.0	4.5	15.4	11.5
All blocks					
Less than 1	69	3.7	4.8	10.6	11.3
1 to 3.9	35	3.3	5.4	11.2	12.2
4 and over	12	5.3	4.1	15.2	16.2

Discussion

All growers know that a rainy year is a scab year and that, with important exceptions, most insects and mites are worst in warm years. These weather effects have influenced survey findings in the contrasting years, 1949 and 1950. Although control has not averaged the same for all types of spray equipment, the greatest differences appeared to come from the way equipment was used, rather than from the equipment itself. There was a consistent trend with all equipment types for control to be poor in the tops of trees. Evidence from the records of cooperating growers shows that the gallonage applied per tree per application was not enough in tall trees. Although control average was poor in the densest trees, only

7 out of 88 cooperating growers whose trees were scored for density were listed as having very thick trees in the test block.

Confirming the results of an earlier study, the present survey found faster discharge correlated with better control in the group using regular sprayers with guns or brooms. With this rather slow kind of equipment, slowness in getting the spray out seemed to limit the effectiveness. With dilute airblast sprayers or with high pressure rigs equipped with masts, there was no consistent trend. There is a suggestion that, with such outfits, extremely rapid discharge was associated with a decrease in control. One might speculate that operators drove too fast when too high a rate of discharge was employed, thereby sacrificing "carry" and penetration of the spray.

This group of growers averaged about 13 applications in both years, with about two more sprays being applied in the Hudson Valley than in western New York. There are possible reasons to justify this difference. The blocks sprayed most often were not cleaner than those sprayed fewer times. Some explanations of very large numbers of treatments in certain orchards are: (1) heavy infestations, (2) heavy local rainfall, and (3) failure to gain control of insects and diseases in the early period of the pest's activity. This last point appears to have been the explanation in the case of apple scab. Growers failing to get early-season control of leaf scab made extra applications in an effort to hold the disease off the fruits; their effort was only partially successful. Growers whose timing of scab sprays during the primary infection period was fair or poor used about one-fourth more gallon of fungicidal spray during the season than did those whose timing was good or excellent. The use of mercury and ferbam fungicides instead of sulfur increased the fungicide bill; such an increase in a particular orchard would have to be justified on the basis of special benefits in control, or in the performance of the trees.

Economic Aspects

Size of business and cost of spraying

The orchards in which these studies were made varied greatly in size of business (table 2). As shown in table 31, the total spraying cost per acre and per tree declined as the acreage of bearing apples increased. The effect of acreage was greatest on the application cost, due to the importance of fixed cost items, depreciation, and interest. Thus, the greater the use of a machine, in hours per year, the lower the cost per hour.

Spray cost analysis

Major cost items as related to grower's spray dollar. Table 32 summarizes the relative importance of the major cost items, calculated from all three cost criteria — cost per acre, cost per tree, and cost per hundred

gallons — expressed in cents of the grower's spray dollar.¹³ In both years, spray and dust materials amounted to 63 cents, by far the largest share. Hence, economy in selection and use of materials may have been more important than economy in methods of application.

The spray equipment cost accounted for the second largest share — 19 cents in 1949 and 20 cents in

Table 31. Relation between size of business and cost of spraying and dusting

(Application cost* and total cost per acre and per tree; 116 blocks of apples, New York State, 1950)

Number of acres in bearing apples	Num- ber of blocks	Cost per acre		Cost per tree	
		Applica- tion	Total†	Applica- tion	Total†
		Dollars		Dollars	
30 or less.....	15	50.53	117.43	1.35	3.17
31-39.....	14	35.41	94.29	1.05	2.78
40-45.....	15	35.78	100.85	0.90	2.56
46-55.....	14	36.05	93.00	1.01	2.63
56-65.....	14	38.88	104.70	1.17	3.10
66-85.....	15	35.41	101.27	0.97	2.78
86-149.....	14	29.37	94.99	0.90	2.87
150 or more.....	15	24.70	74.11	0.77	2.31

*Application cost includes costs of labor, power, and spray equipment.

†Total cost includes application and materials cost.

Table 32. Average cost of spraying and dusting apple trees

(Per acre, per tree, and per 100 gallons; 103 blocks of apples in 1949, 116 blocks in 1950*; New York State)

Cost item	Cost per acre		Cost per tree		Cost per 100 gallons‡		Share of grower's spray dollar†	
	1949	1950	1949	1950	1949	1950	1949	1950
Number of blocks.....	103	116	103	116	90	90		
	Dollars		Dollars		Dollars		Cents	
Spray and dust materials...	62.46	61.88	1.78	1.77	1.20	1.20	63	63
Labor.....	11.06	9.54	0.31	0.27	0.23	0.20	11	10
Tractor power.....	6.55	7.01	0.19	0.20	0.13	0.14	7	7
Spray equipment.....	18.58	19.16	0.53	0.55	0.38	0.37	19	20
Total.....	98.65	97.61	2.81	2.79	1.94	1.91	100	100

*The 1950 figures include the cost of hormones and their application, which were not included in the 1949 cost.

†This is a simple average of three cost criteria, per acre, per tree, and per hundred gallons.

‡Concentrate applications were not converted to a dilute basis for the purposes of this calculation. Their cost was merely based on cost per acre and on cost per tree, hence the cost per 100 gallons is based entirely on the dilute spray blocks.

1950 — almost twice as much as for labor. The smallest item, tractor power, cost 7 cents in each dollar.

Average cost for growers in both years of project. Not all the growers cooperating in 1949 continued to participate in the project in 1950. New orchards were added in 1950. Cost records for both years were obtained for 86 blocks on 83 fruit farms, and are summarized in table 33. The 86 growers cooperating both years reduced their total cost by 8 per cent from 1949 to 1950. The greatest percentage reduction was achieved in labor cost, but the greatest saving in money came from the lowered cost of spray and dust materials.

¹³The way in which the cost figures were determined is discussed in the last section of the appendix.

Table 33. Average spray cost for growers cooperating in both years
(86 blocks of apples on 83 farms, New York State, 1949 and 1950)

Cost items	Cost per acre		Cost per tree		Per cent change* from 1949 to 1950
	1949	1950	1949	1950	
	Dollars		Dollars		
Spray and dust materials.....	64.05	58.99	1.82	1.67	- 8
Labor.....	11.48	10.06	0.33	0.28	-14
Tractor power....	6.88	7.00	0.20	0.20	+ 1
Spray equipment	19.80	18.74	0.55	0.52	- 5
Total cost....	102.21	94.79	2.90	2.67	- 8

*Per cent change was figured individually for cost per acre and for cost per tree; these figures were then averaged.

airblast blocks was close to the general average in 1949, and below it in 1950. Pest control was slightly better than average in both years. The

Per-acre cost with different types of equipment.

The average cost per acre for growers using similar equipment is presented in table 34. Since low spray cost is an important objective in orchard management only when accompanied by adequate control, the control in terms of picked clean fruit was listed next to the total cost. The average total cost for dilute

Table 34. Cost per acre of spraying and dusting apples
(With different kinds of equipment; 103 blocks of apples in 1949, 116 blocks in 1950; New York State)

Type of equipment	Year	Number of blocks	Labor cost	Tractor power cost	Spray equipment cost	Materials cost	Total cost	Control in terms of picked clean fruit*
					Dollars			Per cent
Dilute airblast.....	1949	28	6.02	5.01	23.01	63.25	97.29	93
	1950	38	6.06	5.89	21.62	58.39	91.96	86
Concentrate airblast	1950	16	5.77	4.81	21.22	53.80	85.60	76
High pressure with guns and/or brooms	1949	36	14.11	6.82	10.86	53.04	84.83	86
	1950	23	15.78	9.22	12.07	63.15	100.22	85
High pressure with masts or spray heads	1949	20	11.75	7.98	26.06	70.17	115.96	87
	1950	20	10.06	7.57	20.40	56.72	94.75	83
High pressure with various outlets....	1949	6	17.68	9.59	19.70	93.96	140.93	91
	1950	5	17.58	9.72	20.21	95.17	142.68	83
Wet dust.....	1949	2	13.60	9.98	17.52	97.18	138.28	90
	1950	4	15.21	11.18	18.97	85.24	130.60	61
Spray dusters, variously used.....	1949	4	6.99	3.69	22.60	60.72	94.00	61
	1950	3	6.73	7.74	21.25	101.10	136.82	84
Unclassified.....	1949	7	9.47	5.28	16.22	49.85	80.82	80
	1950	7	7.29	4.57	19.69	55.90	87.45	79
All blocks.....	1949	103	11.06	6.55	18.58	62.46	98.65	87
	1950	116	9.54	7.01	19.18	61.88	97.61	82
Hudson Valley.....	1949	38	13.17	8.74	16.02	68.12	106.05	89
	1950	52	10.54	9.18	20.16	75.30	115.18	82
Western New York.....	1949	65	9.83	5.27	20.07	58.46	93.63	86
	1950	64	8.72	5.25	18.39	50.97	83.33	83

*Only injuries caused by scab, codling moth, red-banded leaf roller, and plum curculio were counted in the determination of these averages. They are therefore a relative index of clean fruit, rather than a completely quantitative one.

average cost for the 16 blocks sprayed with the diverse concentrate machines in 1950 was below the general average, but their average control did not come up to the general average. Blocks sprayed with high pressure rigs with guns and/or brooms had costs below the average in 1949, though not in 1950. The growers using mast equipment exceeded average costs in 1949, but operated at lower than average costs in 1950. Average, or slightly better than average, control was achieved by these two types of high pressure sprayers.

Labor and tractor costs were low for dilute and concentrate airblast machines, but their annual spray machinery cost was high. This was typical of one-man spray equipment. Growers spraying with guns and brooms had relatively high labor costs and a low cost of spray equipment.

While there was little difference in the average pest control for the Hudson Valley and for western New York, the total spray costs for the Hudson Valley blocks in 1949 and 1950 were \$12 and \$32 per acre, respectively, above the western New York average. The biggest share of this cost difference was in the difference in cost of spray materials.

Type of equipment, labor cost, and tractor power cost. Figure 25 shows the wide range in total spray cost per acre. Three growers with an average control of 85 per cent of picked clean fruit had a cost of less than \$40; 13 spent more than \$150 per acre. The largest group, 64 orchards, had costs between \$50 and \$100. Control and total cost appeared to depend less on type of equipment than on the operator.

The frequency distribution of labor cost also had a wide range (figure 26). Eighty-five operations had labor costs below \$11 per acre. There was a clear relationship between the type of equipment used and cost of labor. All airblast sprayers, dilute and concentrate, had labor costs of less than \$14. Most blocks with high labor costs were sprayed with gun and broom equipment. The saving in labor cost with the one-man equipment may well be greater than indicated by the cost-of-labor figures given. The number of year-round men on a fruit farm may be determined by the need for skilled sprayers. Since charges for labor were made only on the basis of the time spent on spraying operations, a saving of this kind has not been accounted for.

Tractor power cost per acre ranged from less than \$3 to \$19, as shown in figure 27. For most blocks, the tractor cost was less than \$7. The power cost per acre was closely related to the rate of application: when fewer gallons were sprayed per hour, tractor time increased and higher power cost resulted.

Cost of spraying and dusting machinery. After materials cost, equipment cost took the largest share of the grower's dollar, as shown in table 32. Of the total equipment cost, which was allocated to the five cost items in table 35, depreciation amounted to 65 per cent, or almost two-thirds. Depreciation and interest together, the fixed cost items in orchard operation, were 78 per cent of the equipment cost.

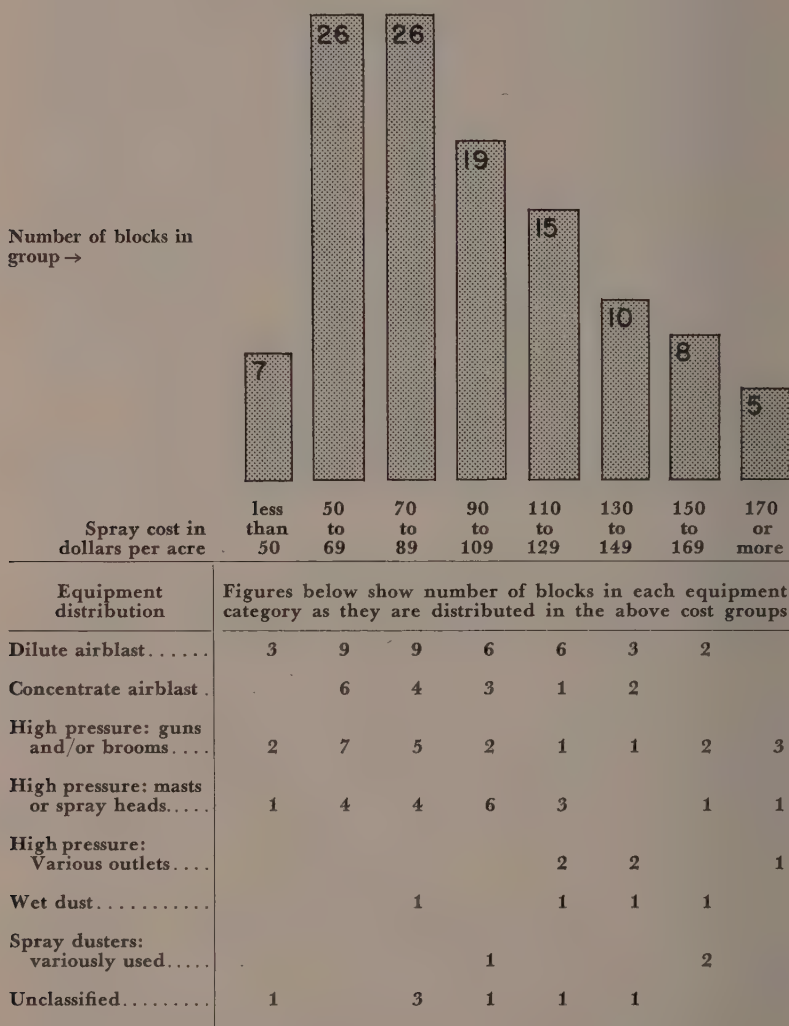


Figure 25. 116 blocks of apples grouped by per acre cost of spraying and dusting in 1950.

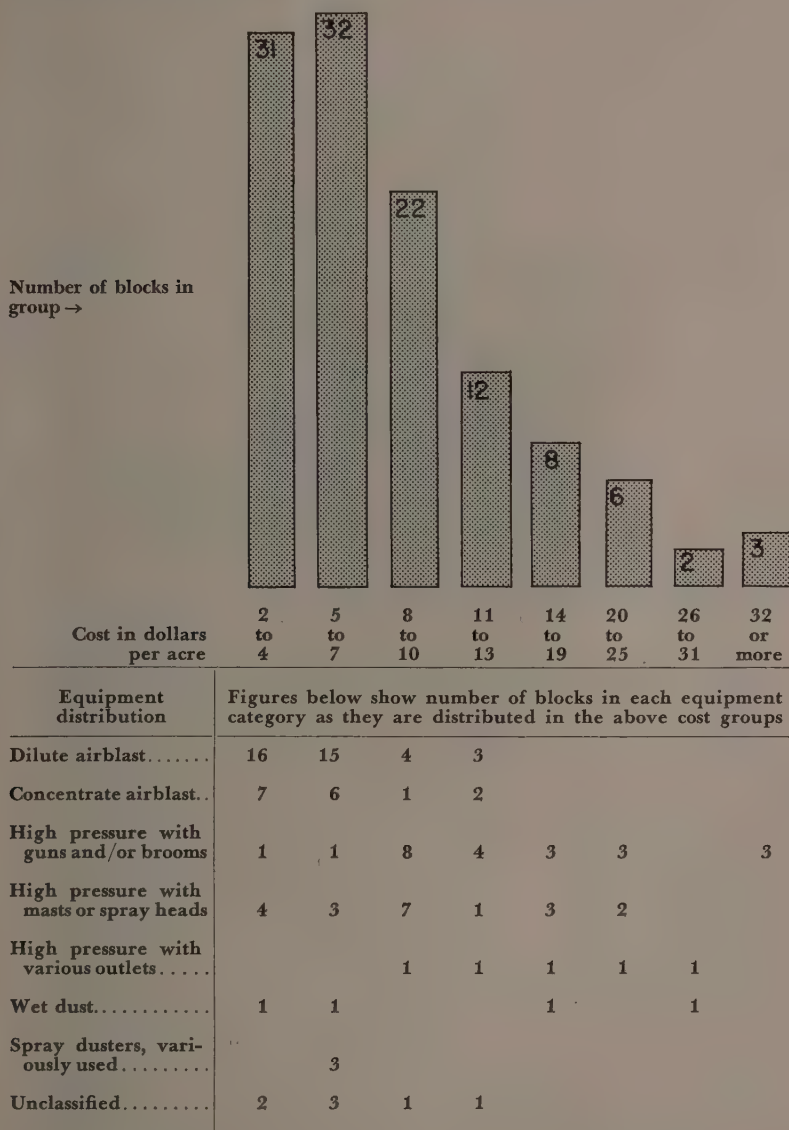
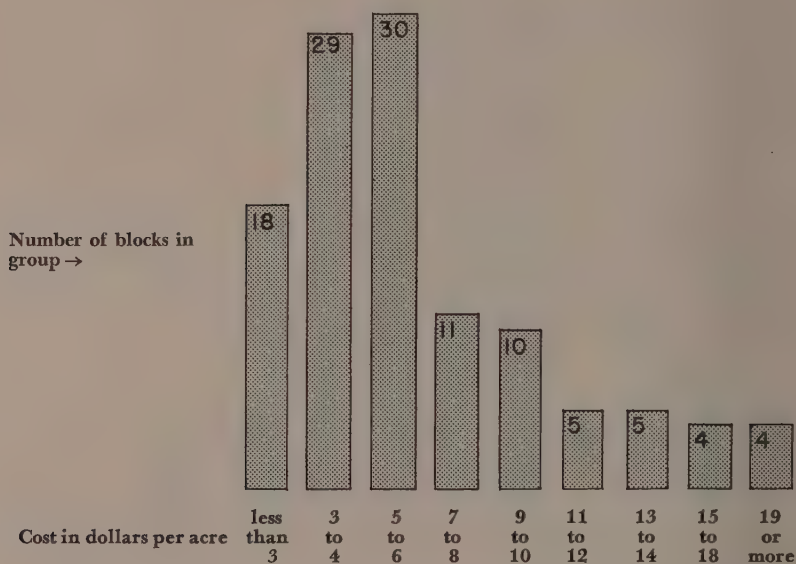


Figure 26. 116 blocks of apples grouped by per acre cost of labor in spraying operation, 1950.



Equipment distribution	Figures below show number of blocks in each equipment category as they are distributed in the above cost groups								
Dilute airblast	8	12	8	3	4	1	1	1	
Concentrate airblast . . .	3	5	6	1	1				
High pressure with guns and/or brooms	2	6	3	4		2	3	1	2
High pressure with masts or spray heads	3	4	6	2	2	1			2
High pressure with various outlets		1	1		1		1	1	
Wet dust			1		1	1		1	
Spray dusters, variously used			1	1	1				
Unclassified	2	1	4						

Figure 27. 116 blocks of apples grouped by per acre cost of tractor power in spraying operation, 1950.

Table 35. Annual equipment cost per acre for spraying and dusting
(With different kinds of equipment; 103 blocks of apples in 1949, 116 blocks in 1950;
New York State)

Type of equipment	Year	Number of blocks	Depreciation*	Interest	Repairs	Oil and grease	Gasoline	Total spray equipment cost
				Dollars		Cents	Dollars	
Dilute airblast.....	1949	28	15.67	3.01	1.14	42	2.77	23.01
	1950	38	14.40	3.00	1.06	35	2.81	21.62
Concentrate airblast.....	1950	16	14.80	3.21	1.19	30	1.72	21.22
High pressure with guns and/or brooms	1949	36	6.47	1.59	1.55	34	0.91	10.86
	1950	23	6.43	1.75	2.15	50	1.24	12.07
High pressure with masts or spray heads	1949	20	16.64	4.11	3.22	50	1.59	26.06
	1950	20	13.47	3.17	2.14	37	1.25	20.40
High pressure with various outlets....	1949	6	12.03	2.13	3.19	37	1.98	19.70
	1950	5	11.87	3.21	2.85	46	1.82	20.21
Wet dust.....	1949	2	12.12	2.78	0.52	34	1.76	17.52
	1950	4	12.55	2.64	1.69	28	1.81	18.97
Spray dusters, variously used.....	1949	4	17.35	3.04	0.83	21	1.17	22.60
	1950	3	12.20	3.08	5.32	22	2.22	21.25
Unclassified.....	1949	7	9.40	1.97	3.23	37	1.25	16.22
	1950	7	14.36	3.04	0.69	29	1.31	19.69
All blocks.....	1949	103	12.00	2.60	1.93	39	1.66	18.58
	1950	116	12.38	2.78	1.62	37	1.90	19.18
Hudson Valley.....	1949	38	10.14	2.29	1.63	41	1.55	16.02
	1950	52	13.22	2.93	1.56	44	2.06	20.16
Western New York.....	1949	65	13.10	2.78	2.10	37	1.72	20.07
	1950	64	11.90	2.71	1.69	32	1.76	18.38

*Depreciation was computed by the constant percentage method. This tends to inflate depreciation charges for new machinery and for machinery whose estimated life is short. Also, because the older machinery was purchased at comparatively low price levels, the depreciation rate for it is relatively deflated. Appendix table 3 shows the magnitude of the differences in depreciation charges calculated by this method and by the "straight line" method.

Depreciation and interest charges were based on three factors; the original cost of the machine, its estimated normal life, and the number of previous seasons' use. In this study, the constant percentage method was used to compute depreciation. Compared with the straight line depreciation method, this one resulted in higher depreciation and lower interest charges. For new and expensive machinery, the increase in depreciation resulting from the use of the constant percentage method was marked. It is also true that the grower's estimate of the normal life of new types of machines could not be based on experience, and was frequently rather conservative. These effects on the depreciation charges used in the study are considered in appendix tables 4 and 5.

Three other factors contributed to the equipment cost: gasoline, oil and grease, and repairs. The cost of these was based on growers' estimates. Compared with computations made by the agricultural engineers, the growers' estimates were sometimes out of line. However, with a large number of observations, the errors of estimate tend to offset each other.

As depreciation and interest resulted in a high fixed cost, equipment

cost per unit of output declined with the use of the sprayer during the season; this decline is illustrated in table 36. Equipment cost per hundred gallons was highest for dilute airblast sprayers applying a small total amount of spray during the season, a combination of low acreage and expensive equipment. This relationship explained most of the decline in spray cost which accompanied an increase in size of business (table 31).

Table 36. Relationship between total usage of predominant* spray equipment on whole farm and cost of spray equipment
(Per acre, per tree, and per 100 gallons; 70 blocks of apples, New York State, 1950)

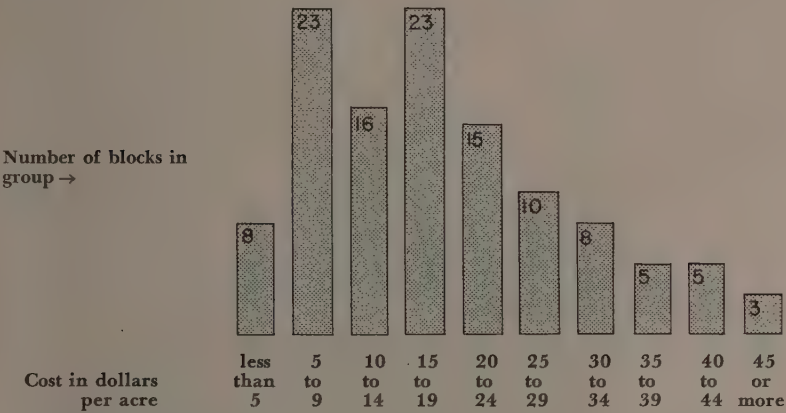
Type of equipment	Total use of sprayer, by number of 100 gallons on whole farm	Number of blocks	Spray equipment cost		
			Per acre	Per tree	Per 100 gallons
			Dollars		Cents
Dilute airblast.	Less than 1,000	3	43.63	1.33	95
	1,000-1,499	2	18.90	0.67	62
	1,500-2,499	11	26.10	0.73	48
	2,500-3,499	11	16.45	0.52	34
	3,500-4,499	6	19.66	0.48	38
	4,500 or more	5	13.37	0.41	26
High pressure with guns and/or brooms	Less than 1,000	4	12.64	0.46	51
	1,000-1,499	7	10.71	0.31	23
	1,500-2,499	9	13.42	0.37	19
	2,500-3,499	2	7.98	0.31	12
	3,500-4,499	1	15.31	0.35	14
High pressure with masts or spray heads	Less than 1,000	3	31.59	0.53	68
	1,000-1,499	9	24.58	0.58	40
	1,500-2,499	4	15.92	0.46	32
	2,500-3,499	4	7.08	0.22	16

*Predominant equipment was defined as equipment used on the test block in at least 75 per cent of the applications.

In figure 28 the orchards were grouped according to their spray equipment cost per acre. The blocks using high pressure equipment with guns and-or brooms had very low equipment costs per acre, which compensated for their higher costs for labor and tractor power. This was a favorable combination for small orchards, in which total usage was relatively low. The other equipment types were scattered over a wide range of equipment cost.

Cost of spray and dust materials. Because of their importance in total spray cost, materials costs were separated, in table 37, according to the materials used. In 1949 the average costs of fungicides was only half the cost of insecticides. As a result of weather differences in the two seasons, the average fungicide costs were higher in 1950, and insecticide costs lower, than in the previous year.

Hudson Valley growers spent \$17 more for fungicides in 1950 than did western New York growers. Their output for fungicides was as high as for all insecticides. Two main factors were responsible for this high cost. (1) 1950 was a difficult scab season in the Hudson Valley because of heavy rainfall, and (2) the Hudson Valley growers relied heavily on expensive fungicides, such as mercury and ferbam materials. The same growers also spent more for insecticides in both years. Costs of hormone materials



Equipment distribution	Figures below show number of blocks in each equipment category as they are distributed in the above cost groups									
Dilute airblast...		3	8	11	5	2	6	1		2
Concentrate airblast.....	1	4	1	2	1	3	2		1	1
High pressure with guns and/or brooms.....	4	9	4	3	1	1			1	
High pressure with masts or spray heads...	2	5	1	2	3	2		3	2	
High pressure with various outlets.....		1		2		2				
Wet dust.....			1	1	2					
Spray dusters, variously used				1	2					
Unclassified.....	1	1	1	1	1			1	1	

Figure 28. 116 blocks of apples grouped by per acre cost of spray equipment in 1950.

Table 37. Cost per acre of spray and dust materials, according to their use*
(103 blocks of apples in 1949, 116 blocks in 1950; New York State)

Type of equipment	Year	Number of blocks	Fungicides	Insecticides				Hormones†	Total materials
				Dormant	Later	Miticides	Total		
			Dollars					Dollars	Dollars
Dilute airblast.....	1949	28	21.63	4.25	33.61	3.76	41.62		63.25
	1950	38	25.07	3.73	22.12	4.45	30.30	3.02	58.39
Concentrate airblast..	1950	16	25.29	3.60	21.10	2.72	27.42	1.09	53.80
High pressure with guns and/or brooms	1949	36	16.14	3.04	29.79	4.07	36.90		53.04
	1950	23	26.11	2.56	26.37	4.99	33.92	3.12	63.15
High pressure with masts or spray heads	1949	20	24.98	5.40	36.28	3.51	45.19		70.17
	1950	20	21.90	4.09	24.45	3.37	31.91	2.92	56.73
High pressure with various outlets.....	1949	6	35.59	6.66	48.56	3.15	58.37		93.96
	1950	5	40.07	3.02	39.73	3.37	46.12	8.98	95.17
Wet dust.....	1949	2	55.07	2.24	36.16	3.71	42.11		97.18
	1950	4	47.57	1.05	33.88	2.42	37.35	0.32	85.24
Spray dusters, variously used.....	1949	4	23.42		35.52	1.78	37.30		60.72
	1950	3	54.05		39.52	5.63	45.15	1.90	101.10
Unclassified.....	1949	7	17.14	3.28	27.02	2.41	32.71		49.85
	1950	7	23.64	0.10	28.17	2.79	31.06	1.20	55.90
All blocks.....	1949	103	21.58	3.92	33.34	3.62	40.88		62.46
	1950	116	26.85	3.10	25.20	3.95	32.25	2.78	61.88
Hudson Valley.....	1949	38	24.01	1.93	36.52	5.66	44.11		68.12
	1950	52	36.11	1.33	30.51	5.11	36.95	2.24	75.30
Western New York	1949	65	19.85	5.05	31.16	2.40	38.61		58.46
	1950	64	19.32	4.54	20.89	3.01	28.44	3.21	50.97

*Insecticides were separated according to their use. "Dormants" consisted mostly of dinitro materials. "Miticides" included dormant-type oil sprays and summer miticides. "Later" insecticides were those used predominantly against the insects on which control checks in the orchards were recorded. Parathion, a multipurpose insecticide, was included in this group.

†No record of hormone applications was taken in 1949. Hence, for strict comparisons between the total costs for the two years, the hormone costs for 1950 may be deducted from the total.

averaged \$5.20 for the 67 growers who used them. Lake belt growers spent more for hormones than did Valley growers. The cost of fertilizer sprays was not included in spray materials cost.

For all spray materials, western New York growers spent \$10 less per acre in 1949, and \$24 less in 1950, than fruit farmers in the Hudson Valley. Both areas were equal in their percentage of clean fruit, as indicated by the damage done by insect pests and apple scab.

Figure 29 shows a wide range in expenditures for spray and dust materials. Seventy-three growers spent more than \$30, but less than \$70, per acre. No clear relationship was found between equipment type and the amount spent for materials. Individual records showed that some growers with a low materials cost obtained control as good or better than high cost growers.

Effect of yield and pest control on cost per bushel

Yield figures for the blocks in the project were not available; only those trees sampled for insect and disease control provided them. When the number of bushels harvested from sample trees was multiplied by the

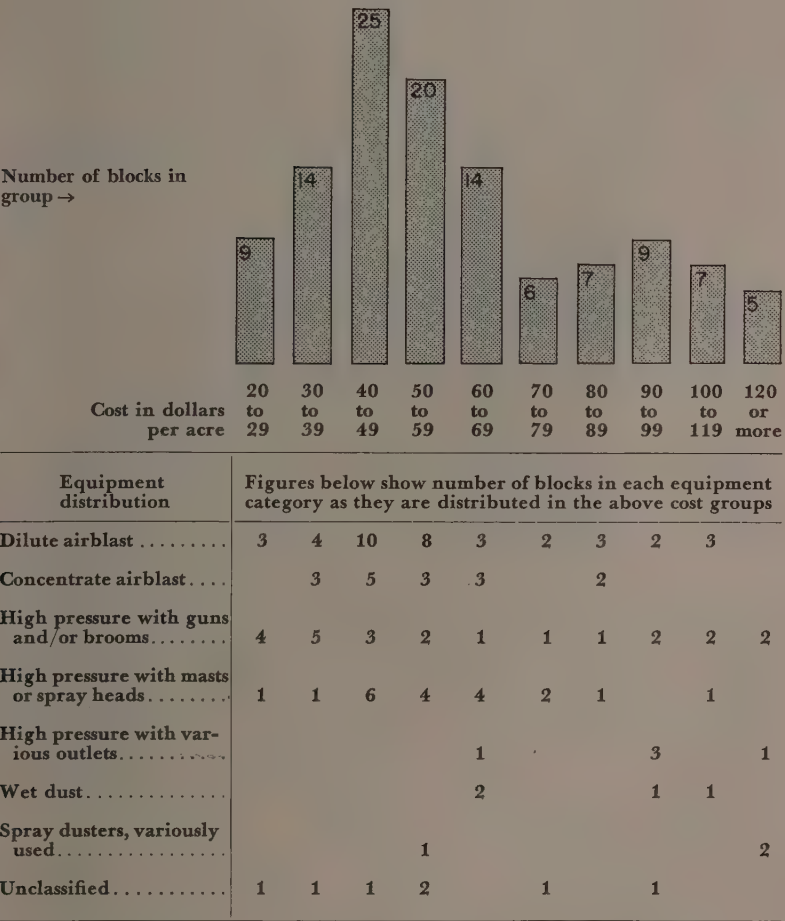


Figure 29. 116 blocks of apples grouped by per acre cost of spray and dust materials in 1950.

number of trees, the computed yield per acre was relatively high. Downward adjustments were made for the percentage of injured fruit recorded for each orchard, and for 25 per cent off grade in size, shape, finish, color, and injury by pests ignored in this study. Even after such reductions, these yields were high compared with averages of cost accounts for other commercial fruit farm operations. The sample trees were evidently larger and higher yielding than the average of all trees in the block. Nevertheless, these yields were comparable from block to block.

The computed yields were used in table 38 to illustrate the effects of the three factors, yield, control, and index of spray cost, on cost of spraying per bushel. Any of these factors is important. The combination of high yield, low index of spray cost, and above average control resulted in a low

Table 38. Effects of yield, control, and index of spray cost on the cost of spraying per bushel (113 blocks of apples, New York State, 1950)

Relative yield of picked fruit of marketable size and color*	Control†	Index of spray cost‡		
		Less than 85	85-110	Over 110
		Spray cost per bushel of clean and marketable fruit		
		Cents		
Low-yield orchards	Below average	60	61	189
	Above average	31	32	72
Medium-yield orchards	Below average	16	31	45
	Above average	13	23	36
High-yield orchards	Below average	19	31	32
	Above average	12	16	24

*The estimated yield was based on four sample trees in each block. The yield classes were as follows: low—less than 338 bushels per acre; medium—338-562 bushels per acre; high—over 562 bushels per acre. They were reduced by 25 per cent for fruit off-grade in size, shape, and color, and for blemishes caused by spray, weather, or insects other than the ones scored.

†The survey orchards in 1950 averaged 82 per cent of fruit free from injury by scab, codling moth, curculio or red-banded leaf roller.

‡The spray cost index was based on all three cost criteria; cost per acre, per tree, and per 100 gallons.

of 400 bushels per acre with the same control would have reduced the spray cost per bushel to 29 cents.

Effect on cost of number of applications and gallonage

As the number of fungicide applications increased, the cost of fungicide materials rose sharply (table 39). A trend of rising costs for fungicide materials was also evident as the gallonage of fungicidal spray increased; table 40 shows this relationship for both years studied. It was shown in the previous section that fungicides were included in 75 per cent of the 1949 sprays, and 85 per cent of the 1950 sprays. Hence, the effect of the increasing number of gallons of fungicide spray was important in the total spray

spray cost per bushel, only 12 cents per bushel of clean and marketable fruit. In contrast, blocks with low yield, with a high spray cost index, and with below average control had a spray cost of \$1.89 per bushel.

The average spray cost per acre was \$98 for all growers in both seasons studied; their average control was 85 per cent of clean picked fruit. With an average yield of 200 bushels per acre of marketable size and color, and 85 per cent clean fruit, the average spray cost per bushel would have been 58 cents. A yield

cost. So striking was the increase in total spray cost that the rate of fungicidal application was considered a dominant cost factor. The growers who succeeded in controlling scab early in the season had a twofold advantage, low cost and good control.

Effect of organic fungicides on cost

Judging by table 41, the cost of fungicides per acre and per tree advanced with the increasing number of mercury applications, both in the Hudson Valley and the western New York blocks. Most of the growers using mercury also used ferbam, a somewhat expensive fungicide.

The cost of the scab spray program depended on two factors: the price of the materials used and the total quantity applied. Although fewer organic fungicides were used in western New York, the higher level of the fungicide materials cost in the Hudson Valley was not due to the use of expensive fungicides alone. In 1950, scab was more difficult to control in the Hudson Valley. A greater number of applications resulted in a larger quantity of spray applied, but in each area the mercury and ferbam programs increased the cost of scab control.

Table 39. Relation between total number of fungicidal applications and cost of fungicide materials
(116 blocks of apples, New York State, 1950)

Number of fungicidal applications	Number of blocks	Cost of fungicide materials	
		Per acre	Per tree
Hudson Valley		Dollars	
7.5- 9.4.....	5	28.90	0.81
9.5-11.4.....	11	28.07	0.95
11.5-13.4.....	16	35.96	0.93
13.5-15.4.....	14	36.08	1.05
15.5 or more.....	6	57.35	1.54
Western New York			
Less than 7.5.....	8	14.68	0.39
7.5- 9.4.....	17	15.33	0.47
9.5-11.4.....	26	20.34	0.59
11.5-13.4.....	10	23.62	0.70
13.5-15.4.....	3	31.03	0.76
All blocks			
Less than 7.5.....	8	14.68	0.39
7.5- 9.4.....	22	18.42	0.54
9.5-11.4.....	37	22.64	0.70
11.5-13.4.....	26	31.22	0.84
13.5-15.4.....	17	35.19	1.00
15.5 or more.....	6	57.35	1.54

Table 40. Effect of quantity of fungicidal sprays applied on cost of fungicide materials and on total spray cost
(95 blocks of apples in 1949, 88 blocks in 1950, New York State)

Gallons of fungicidal spray per acre; whole season	Number of blocks	Cost of fungicide materials		Total spray cost	
		Per acre	Per tree	Per acre	Per tree
Hudson Valley					
1949		Dollars			
Less than 2,500	7	13.43	0.42	74.28	2.29
2,500-4,499...	13	23.79	0.67	102.43	2.94
4,500-6,499...	11	26.15	0.81	115.04	3.67
6,500-8,499...	2	25.91	0.74	111.58	3.20
8,500 or more...	1	62.53	1.54	221.08	5.47
1950					
Less than 2,500	4	21.54	0.64	60.35	1.94
2,500-4,499...	12	32.06	0.93	103.58	3.10
4,500-6,499...	11	37.33	1.16	126.05	3.90
6,500-8,499...	4	43.94	1.07	165.48	4.00
8,500 or more...	2	66.38	1.64	231.32	5.72
Western New York					
1949		Dollars			
Less than 2,500	12	9.40	0.32	56.03	2.01
2,500-4,499...	28	15.04	0.48	77.28	2.42
4,500-6,499...	14	23.97	0.62	116.63	2.90
6,500-8,499...	4	20.22	0.76	159.45	4.06
8,500 or more...	3	39.87	0.83	188.40	3.67
1950					
Less than 2,500	8	9.18	0.33	52.43	1.82
2,500-4,499...	25	16.50	0.52	71.02	2.19
4,500-6,499...	17	23.15	0.58	98.57	2.36
6,500-8,499...	2	26.81	0.71	140.34	3.72
8,500 or more...	3	36.88	0.78	157.91	3.33

Table 41. Relationship between number of mercury applications and cost of fungicide materials
(116 blocks of apples, New York State, 1950)

Number of mercury applications	Blocks	Blocks in group also sprayed with ferbam	Cost of fungicide per acre	Materials per tree
		Number	Dollars	
Hudson Valley				
Less than 1.....	17	12	30.87	0.95
1 to 3.9.....	23	20	34.50	0.98
4 or more.....	12	12	46.64	1.23
Western New York				
Less than 1.....	52	11	18.27	0.51
1 to 3.9.....	12	1	23.87	0.76

Relation between total applications and total spray cost

The increasing number of applications and increasing gallonage for both insect and disease control resulted in a sharp increase in average total spray cost (tables 42, 43). Yet the average percentage of picked

clean fruit was better in the orchards receiving fewer applications or less gallonage (tables 25 and 26).

Relation between scab control and cost of fungicides

Individual orchards were rated from excellent to very poor in scab control, according to the percentage of fruit with scab (table 44). Orchards rated good or better had a lower average cost of fungicide materials than the orchards with a rating of fair or below. On the average, good scab control was generally obtained at a lower cost than poor control, for less spraying was necessary when the primary infection was kept under control (see tables 27 and 29).

Table 42. Relation between number of applications for insect and disease control and total spray cost
(116 blocks of apples, New York State, 1950)

Number of applications for insect and disease control	Number of blocks	Total spray cost	
		Per acre	Per tree
Hudson Valley			
9.5-11.4.....	6	84.34	2.90
11.5-13.4.....	14	115.59	3.31
13.5-15.4.....	18	114.63	2.97
15.5 or more.....	14	128.70	3.86
Western New York			
Less than 9.5.....	9	56.83	1.72
9.5-11.4.....	29	84.49	2.31
11.5-13.4.....	18	88.79	2.60
13.5-15.4.....	6	92.99	2.54
15.5 or more.....	2	107.77	2.88
All blocks			
Less than 9.5.....	9	56.83	1.72
9.5-11.4.....	35	84.46	2.41
11.5-13.4.....	32	100.51	2.91
13.5-15.4.....	24	109.22	2.86
15.5 or more.....	16	126.08	3.74

Discussion

On the average, the growers with the largest acreage of fruit spent only about half as much for the application job as the group with the smallest acreage. This is probably because they could afford to own more efficient machinery, and used each machine more hours per year. The large-scale growers also appear to have spent a little less for materials.

The average cost of spraying was about \$98 per acre, or \$2.80 per tree. The average cost of 100 gallons of mixed material applied to the tree was about \$1.92; this covers materials and their application. Of the total cost, 63 per cent was for materials, 19 per cent for spray equipment use, 10-11 per cent for labor, and 7 per cent for tractor use. Growers appear to have spent a little less for spraying in 1950 than in 1949. Concentrate sprayers had slightly lower costs than any other equipment class in 1950, dilute airblast machines came next, then regular sprayers with masts or spray heads; high pressure sprayers with guns and/or brooms had the highest total cost. However, the widely divergent group of concentrate sprayers averaged slightly poorer control than the other machine types represented by 16 or more blocks. In both years the costs were lower in western New York than in the Hudson Valley orchards. The difference in spray cost between these two fruit areas was evident whether the measure used was cost per acre, per tree, or per bushel of picked clean fruit. No difference was observed in pest control for these two areas.

Table 43. Effect of quantity of spray applied for insect and disease control on total spray cost (86 blocks of apples, New York State, 1950)

Gallons per 1,000 cubic feet of tree volume; whole season	Number of blocks	Total spray cost	
		Per acre	Per tree
		Dollars	
Hudson Valley			
Less than 10.....	1	86.97	1.44
10-12.9.....	9	108.06	2.97
13-15.9.....	7	109.44	3.35
16-18.9.....	6	126.04	4.21
19-21.9.....	4	155.35	3.94
22 or more.....	5	146.62	4.13
Western New York			
Less than 10.....	7	56.98	1.72
10-12.9.....	18	79.29	2.17
13-15.9.....	12	86.43	2.40
16-18.9.....	8	81.20	2.23
19-21.9.....	4	95.49	2.17
22 or more.....	5	134.37	3.72
All blocks			
Less than 10.....	8	60.73	1.68
10-12.9.....	27	88.88	2.44
13-15.9.....	19	94.90	2.75
16-18.9.....	14	100.42	3.08
19-21.9.....	8	125.42	3.06
22 or more.....	10	140.49	3.92

Table 44. Relation between scab control* and cost of fungicide materials per acre (115 blocks of apples, New York State, 1950)

Orchards rated for scab control	Number of blocks	Fungicide materials cost per acre
Dollars		
Hudson Valley		
Excellent.....	13	36.96
Very good.....	12	33.34
Good.....	10	26.20
Fair.....	12	40.95
Poor.....	5	48.79
Western New York		
Excellent.....	21	21.42
Very good.....	14	13.73
Good.....	13	19.62
Fair.....	7	17.94
Poor.....	8	25.44
All blocks		
Excellent.....	34	27.36
Very good.....	26	22.78
Good.....	23	22.48
Fair.....	19	32.47
Poor.....	12	34.41

*As rated by specialists in the Department of Plant Pathology, according to percentage of fruit with any scab.

Rating	Per cent fruit with any scab	
	McIntosh	Other Varieties
Excellent.....	0- 1.99	0- 1.24
Very good.....	2- 5.99	1.25- 3.74
Good.....	6-13.99	3.75- 8.74
Fair.....	14-29.99	8.75-18.74
Poor.....	30 or more	18.75 or more

Individual orchards in each equipment class had low costs while others had high costs, and control was not consistently better for the growers with high costs. Frequently, low-cost blocks had good control, and high-cost blocks represented efforts to check diseases or insects after much damage was done. The airblast sprayers, both dilute and concentrate, were low in labor cost and tractor cost, but rather high in annual spray equipment cost, due partly to high charges for depreciation. The cost of materials was a little lower for concentrate sprayers than for the other types.

Fungicides cost much more for the Hudson Valley growers than for those in western New York, both because they used more organic materials and because they applied more fungicidal sprays. The liberal use of mercury fungicides made the program more costly, and ferbam had a less pronounced effect in the same direction.

The most important measure of costs is the cost per bushel of clean fruit. The three most important factors influencing cost per bushel proved to be: (1) yield, (2) percentage of fruit clean, and (3) spraying cost per acre or per tree. In this last category, materials were of greatest importance. Large numbers of applications, or large total gallonages per acre, naturally increased the total spray cost. Excessive spraying was avoided by growers who applied effective materials, thoroughly, at well-chosen times during the early and middle periods of the spraying season. Good control of scab cost less than poor control, largely because growers who timed early-season scab sprays well avoided the need of extra, late-season treatments. Thoroughness in early-season sprays may have been equally important, but thoroughness could not be judged precisely in this study.

General Discussion and Conclusions

It has been the purpose of this study to find the profitable combinations of orchard equipment and spraying methods. Beyond the specialized research of each, the five cooperating departments had three objectives:

1. To determine whether any type of orchard equipment promises superior pest control at reasonable cost.
2. To isolate the factors which improve spray efficiency, and to assess their relative importance.
3. To analyze spray practices that result in effective pest control at reasonable cost.

This is a study of the practices and results in commercial orchards. The objective was to determine *why* the results were satisfactory or unsatisfactory in each case: whether they were due to machinery, materials, or timing of applications. There are such wide variations in the difficulty of controlling each disease and insect pest, and in other matters such as size,

spacing, and density of trees, that only rather large differences deserve consideration. These irregularities in individual orchards average out pretty well when the results of a fairly large group of growers are calculated. There were enough blocks cared for by dilute airblast sprayers, by regular high pressure sprayers with guns and/or brooms, and by regular sprayers equipped with masts or spray heads to make these averages fairly dependable. Although represented by sixteen blocks, concentrate sprayer results cannot be as dependably judged, because growers are just learning the technique of this new method and because of the tremendous differences in design and power of the concentrate rigs. Some other classes of equipment were used in so few of the survey orchards that their averages can be considered as giving only a rough clue to their performance.

Individual growers obtained good pest control, combined with low spray cost, in orchards sprayed with each of the four major machine types. On the other hand, there were growers using each of the four machine types who had poor control and excessive costs. More difference was found in pest control and in spray cost within each equipment class than between the equipment class averages. Thus, to a large extent, spray cost and pest control depended not so much on the type of spray equipment as on the way in which the machines were used.

Dilute airblast operations

The size of business was a major factor determining the selection of spray equipment. In this study, dilute airblast sprayers were used in orchards averaging approximately 80 acres of bearing apples, but the size of individual orchards ranged widely above and below the average. The high investment required for these machines, and the method of determining their normal life,¹⁴ resulted in high depreciation charges, high equipment overhead, and, consequently, in high annual spray equipment costs. Compensatory savings, however, were made in costs for labor and tractor power. Figures for man and tractor hours were low because relatively few hours were spent in covering the orchard, and because it was a one-man operation. This combination of input factors (high equipment cost with low labor and power cost) was favorable on large farms, where rapid operation was essential for timely coverage, where the equipment overhead was spread over many acres, and where dependable man labor was scarce.

In both years, the dilute airblast operations studied were above the project average in control, while their spray cost was slightly below the average in 1949, and \$6 lower than the general average in 1950. At present, a large dilute airblast sprayer costs nearly \$5000, and additional investment for water is as necessary or more necessary for efficient opera-

¹⁴Growers had many years' experience with their high pressure sprayers. Airblast equipment, on the other hand, had only recently been introduced. Hence, in the case of airblast sprayers, growers' estimates of the expected normal life of the equipment averaged fewer years than for high pressure sprayers. The shorter normal life increased the depreciation charges.

tion than in the case of high pressure sprayers. The minimal acreage necessary to justify such expensive equipment depends on many things, but for growers with less than 60 acres of bearing fruit the main justification would be serious labor problems.

Concentrate airblast operations

The 16 concentrate sprayers varied considerably in design. Some had round, hand-operated air outlets, some had round, rotating outlets, some had small, while others had large, slot-shaped outlets. The rate of discharge ranged from less than 3 to 15 gallons per minute. Air volume varied from 4000 to more than 40,000 cubic feet per minute. The smallest concentrate sprayers had tanks holding 100 gallons while the largest held 500 gallons. The concentration of the mixture varied from 2X to 4X or, rarely, 6X, in the converted dilute airblast machines, to 8X or 10X in some of the other machines designed specifically to handle concentrates. Because of the diversity in physical characteristics of the machines that applied concentrates in the survey orchards, and because growers lacked experience with the concentrate airblast method, the averages for costs and control are probably less meaningful than the averages for the other major groups. In this study too few blocks were cared for with each of the special types of concentrate machines to throw any light on possible relationships between control and such features as volume or velocity of airblast, location or shape of air outlet, water pressure, or concentration of spray used.

The average total cost per acre of spraying with concentrates was 15 per cent below the average for all farms. The equipment costs were slightly above average, but the costs for labor, tractor power, and materials were well below average. There was no correlation between the cost of the concentrate programs and the control achieved in individual orchards. As in the other equipment classes, high control was obtained by individual growers at a cost considerably below the general average.

The data from several of the concentrate-sprayed blocks indicate that pest control can be obtained at relatively low cost with this method of application. The degree of control and the efficiency of the operation depends, as in all orchard spraying, on the grower's understanding of his problems, his equipment, and on his ability to plan and carry out a well-organized spray program.

High pressure operations

Growers using high pressure sprayers with guns and/or brooms had a relatively low capital investment and a low equipment overhead because of lower original cost, and because these machines had been depreciated in many previous seasons' use. However, the machines applied relatively few gallons per hour of operation. More man hours and more tractor hours were required, and labor and power costs were high. On small

acreages the low rate of application was not necessarily a serious disadvantage, as most growers were able to apply timely sprays for adequate control. The input combination of lower equipment cost with higher labor and power cost was better adapted to small farms.

The gun and broom equipment was used on farms averaging 52 acres of bearing apples in 1949, but only 41 acres in 1950, with a considerable range above and below the averages. The decrease in the number of growers using these machines, and the decline in their average acreage from 1949 to 1950, might be an indication that these sprayers are being replaced by other, more efficient, types on the large farms.

Control in this equipment class was slightly below the general average in 1949, but better than average in 1950. The cost per acre was considerably below the survey average in 1949, but it exceeded the average cost in 1950. On the basis of this study it seems probable that growers on farms of less than 40 acres of bearing apples might well continue to use high pressure sprayers.

High pressure sprayers with masts or spray heads represent a capital investment almost twice as high as that of gun and broom equipment. This was because the equipment was newer, particularly the masts, and the pumps were, in general, larger. As mentioned before, because of the difficulty of calculating normal life and depreciation, all new, and thus higher priced, equipment results in this study in a higher equipment cost. However, the investment was considerably less than that for airblast machines.

The rate of application for this equipment exceeded that for gun and broom equipment in most, but not all, cases, and often approached that of airblast machines, particularly where a transport rig was used. The pump size was the limiting factor. A number of observations suggest that mast equipment should not be used where the pump capacity is 35 gallons per minute or less.

Masts or spray heads were used on farms averaging approximately 58 acres of bearing apples in 1949 and 1950, intermediate in size between the smaller gun-and-broom-sprayed orchards and the larger airblast-sprayed orchards. Control was slightly below average in 1949 and somewhat better than average in 1950. The cost per acre was considerably higher than the average in 1949, but slightly less than average in 1950. Some of this equipment, when fitted to the correct pump, might well reduce labor requirements and might provide a satisfactory output for small and medium sized orchards. This study provided no basis for judging the airblast attachments now offered for high pressure sprayers.

Application cost and size of business

The application cost, including the costs for labor, tractor power, and spray equipment, declined as the size of business increased. Growers with less than 30 acres in bearing apples had an average application cost of \$50

per acre. This declined as the size of business increased, so that growers with more than 150 acres of bearing apples spent only \$25 on application costs.

Factors affecting rate of application

Marked differences in operating efficiency were found for different machine types. High pressure sprayers with guns and/or brooms averaged approximately 40 minutes for a round trip applying 500 gallons. Dilute airblast sprayers, averaging approximately three tanks per hour, were twice as fast in applying 500 gallons. High pressure sprayers with mast equipment were intermediate in rate of spray discharge.

In spite of the great difference in rates of application for the group, some growers with gun and/or broom equipment applied 500 gallons about as fast as the most efficient airblast operators. The spread in time between growers using the same equipment indicates opportunities for saving.

The time and motion studies revealed that growers in the fastest group were outstanding in all three operations that are part of the spray cycle. Efficient discharge equipment reduced their spray time, and they spent little time in travelling to and from the source of water, and in filling the sprayer tank.

There was evidence that many growers could improve the discharge capacity of their sprayers by relatively minor mechanical adjustments or changes, requiring a fraction of the outlay needed for the purchase of new equipment. Efficiency could also be improved by minor changes in water supply facilities. Water filling time was reduced when overhead tanks had outlets of at least three inches in diameter, and by the use of large capacity pumps when the spray tank was filled from a filler truck or from a source of water. It was important to have the spray materials conveniently located, and to mix and add them while the water was running into the tank.

The traveling time was markedly reduced when the source of water was close to the block, or when a transport truck was used. The average capital invested in the permanent water supply system was low relative to the amount invested in spray machinery. A small investment in improved water supply facilities frequently resulted in marked improvement in spraying efficiency.

Effectiveness of pest control decreased in the tops of trees, especially when trees were much higher than 20 feet. Sufficient opening of the trees was another necessary condition for effective control.

Spray practices affecting spray cost and pest control

There were no simple relationships between pest control and the number of applications or the total quantity of spray applied. Because thorough scab control in the early season eliminated the need for applications

during late summer, it gave superior scab control at lower cost. Appropriate timing of scab sprays assured control with smaller quantities of scab spray, and consequently at lower cost. Injuries from codling moth and red-banded leaf roller decreased when growers increased insecticidal applications. Injuries from curculio, on the contrary, showed little relation to the number of insecticidal applications.

In both survey years spray and dust materials accounted for 63 per cent of the total spray cost. The selection of toxicant materials, appropriate timing, and the rate at which the materials were applied were the most important factors in the total spray bill. Programs based on sulfur scab protectants were cheaper and no less effective, on the average, than spray schedules relying heavily on mercury, ferbam, or other organic fungicides. This appears to suggest that growers should apply these expensive fungicides only when they need their particular benefits.

Individual growers saved materials by spraying only one side of the tree at a time, covering the other side after an interval of several days. Although this practice cannot be universally recommended, it may offer opportunities for lower spray cost in some cases, especially where trees are not very large or dense.

The cost per bushel of marketable fruit was the crucial figure in determining the marginal cost. The cost per bushel of clean, marketable fruit depended even more on the yield per acre and the control, in terms of picked clean fruit, than on the cost of spraying an acre. Orchards with high yield and good control had the lowest average spray cost per bushel.

Appendix

Appendix table 1. Cost of spraying in relation to cost of growing apples (New York cost-account farms)

Cost items and yield	All farms*		Sample farms†	
	1937-40 Average	1941-44 Average	Champlain 1949	Hudson 1949
	Dollars per Acre		Dollars per Acre	
Spray and dust materials.....	11.94	14.75	44.58	55.41
Labor.....	3.66	5.99	5.34	13.99
Power (horse and tractor).....	1.98	2.07	11.42	14.51
Spray equipment.....	3.76	4.14	12.30	20.75
Total spray cost.....	21.34	26.95	73.64	104.66
Total growing cost.....	60.50	67.00	187.76	228.82
	Per cent		Per cent	
Spray cost in per cent of total growing cost	35	40	39	46
	Bushels		Bushels	
Bushels packable fruit per acre.....	160	183	458	283
	Cents		Cents	
Spray cost per bushel.....	13	15	16	37

*Data adapted from *Cost and Efficiency in Spraying Apples*, p. 6, by K. L. Robinson (thesis for degree of M.S., Cornell Univ., July 1947).

†Data adapted from *Fruit Farms Analyzed*, p. 27, by G. P. Scoville (A.E. 769, Dept. Agr. Econ., Cornell Univ., February 1951). The data in each column are for single orchards in the Champlain Valley and Hudson Valley areas.

Spray Machines in the Survey, by Manufacturer and Design

Early in the tabulation of field data, control and cost figures were summarized according to the specific machinery classification in Appendix table 2. Such a detailed classification appeared desirable to allow for differences in mechanical design and in growers' spray practices. However, fine differentiation resulted in a large number of equipment classes, some represented by only one or two orchards. A broader, more inclusive equipment classification was then selected for this report. Each operation was classified according to the predominant equipment type used in 75 per cent or more of the applications. A brief definition of each equipment class follows.

Dilute airblast

Machines using toxicants in dilute form, and applying them with an airblast.

Concentrate airblast

Machines using toxicants in concentrations of 2X or above, and applying them with an airblast.

High pressure

Machines of different makes and models included under the high pressure categories applied the toxicants in dilute form, with approximately 400-600 pounds of pressure. Water pressure without airblast carried the spray to the tree. Details on individual machines are listed in tables 2a, 2b, 2c.

Appendix table 2. List of predominant type of equipment used
(116 selected blocks of apples, New York State, 1950)

Predominant type of equipment	Number of blocks
I Dilute	
A. Airblast	
Fixed outlet	
Bean Speed Sprayer—1 side discharging.....	21
Bean Speed Sprayer—2 sides discharging.....	10
Bean Speed Sprayer—1 and 2 sides discharging.....	1
Friend Air Blast Sprayer.....	2
Hardie Air King.....	1
Schottler rig (home built).....	1
Oscillating outlet	
Myers Silver Cloud.....	2
B. High pressure	
Guns.....	15
Brooms.....	2
Guns and brooms.....	6
Masts	
Gun nozzles—high.....	5
Gun nozzles—low.....	6
Boom nozzles—high.....	3
Mixed nozzles.....	3
Oscillating spray heads	
Mechanical.....	2
Manual.....	1
High pressure: various outlets.....	5
II Concentrate airblast	
A. Fixed outlet	
High volume	
Low concentration—Bean Speed Sprayer.....	3
High concentration—Hardie Orchard Mist Concentrate Sprayer.....	4
Low volume—Niagara Super-Cyclone Liqui-Duster, Buffalo Turbine— Spray Duster.....	3
B. Moving outlet	
Manual—Lawrence Mist-o-mite.....	2
Mechanical—Lawrence Mist-o-matic.....	4
III Wet dust	
Niagara—Super-Cyclone Liqui-duster.....	2
Home built.....	2
IV Spray-dusters variously used	
Buffalo Turbine—Spray duster.....	1
Niagara Super-Cyclone Liqui-duster.....	2
V Unclassified*.....	7
Total.....	116

*This group includes one dry dust operation. The other six blocks were sprayed with various combinations; no one type of equipment was used 75 per cent of the time.

Appendix table 2a. High-pressure sprayers with guns and/or brooms, 1950

Equipment company	Number of seasons used before 1950	Tank size	Pump capacity	Original cost, including gun, broom, hose, etc.*	Average value in 1950 season
		Gallons	Gallons per minute	Dollars	Dollars
Myers	3	400	35	1,868	853
Friend	5	500	35	1,780	554
Bean	3	500	35	2,482	1,450
Bean†	5	400	35	724	229
Hardie	8	400	23	378‡	135
Friend	3	400	35	1,800	937
Friend	11	500	35	815‡	151
Friend	9	600	35	1,176	277
Bean	4	400	35	1,700	476
Hardie	2	400	23	1,907	1,097
Bean	4	500	35	1,735	900
Friend	5	400	35	1,189	357
Friend	4	450	25	1,536	571
Friend	1	450	35	1,640	1,224
Bean	3	500	35	1,820	948
Iron Age	1	450	40	1,828	1,499
Myers	5	500	50	2,107	844
Bean	5	400	35	1,799	787
Bean	4	400	35	1,613‡	876
Bean	2	600	60	1,895	1,284
Friend	2	1,000	60	1,275	858
Hardie	1	600	35	1,302‡	1,047
Average	4.1	489	36.7	1,562	789

*Guns, brooms, hose, etc. were depreciated on a 5-year basis.

†Home assembled.

‡Bought second-hand.

Appendix table 2b. High pressure sprayers with masts or spray heads, 1950

Equipment company	Number of seasons used before 1950	Tank size	Pump capacity	Original cost, including mast, spray head, etc.*	Average value in 1950 season
		Gallons	Gallons per minute	Dollars	Dollars
Bean	12	500	35	1,900	651
Friend	3	600	60	3,298	1,682
Friend	1	600	60	3,650	2,724
Bean	4	500	35	2,489	1,208
Bean	12	600	55	1,500	416
Hale	1	500	100	2,925	2,094
Hale	1	500	100	2,925	2,094
Bean	3	400	20	1,452	799
Bean	5	500	35	1,455	336
Bean	1	400	35	3,092	2,038
Hale	1	500	100	3,151	2,675
Iron Age	3	500	40	2,500	1,489
Hardie	9	400	35	1,785	571
Bean	5	600	60	2,196	639
Myers	1	600	50	2,220	1,646
Home assembled	2	600	50	2,677	1,706
Friend	10	400	45	1,020	760
Iron Age	2	600	50	2,750	1,488
Iron Age	1	600	50	3,745	2,787
Iron Age	1	600	50	2,970	2,116
Average	3.9	525	53.2	2,485	1,496

*All masts, spray booms, and spray heads were depreciated on a 5-year basis.

High pressure with guns and/or brooms

When the high-pressure sprayers were used with single outlet nozzles, directed by hand, they were placed in the gun category; when used with multiple nozzles, directed by hand, they were classified in the broom category. Some growers used both gun and broom at the same time; others switched from gun to broom in different applications.

High pressure with mast or spray heads

High-pressure sprayers were classified under the mast or spray head category if the spray was delivered through nozzles mounted on a mast (vertical boom), or in nozzle banks. Some of these devices were fixed, others oscillated mechanically, and others were operated by hand.

High pressure with various outlets

High-pressure machines on which no single kind of discharge equipment was used in as many as 75 per cent of the applications.

Wet dust

Machines in which the toxicants were primarily in the form of dust, with water injected into the airstream.

Spray dusters, variously used

Machines which applied dry dust, wet dust, and concentrates in different applications. The machines did not necessarily differ from those consistently applying wet dust.

Unclassified

In this group no one type of equipment was used in at least 75 per cent of the applications. Since there was just one block consistently cared for with dry dust, it was listed here.

Appendix table 2c. High pressure: various outlets, 1950

Equipment company	Number of seasons used before 1950	Tank size	Pump capacity	Original cost, including guns, brooms, mast, etc.*	Average value in 1950 season
		Gallons	Gallons per minute	Dollars	Dollars
Bean	5	500	35	1,886	817
Bean	8	500	35	2,593	795
Hardie†	5	400	35	1,029	603
Bean	1	500	35	2,718	1,512
Iron Age	6	500	40	1,851	579
Average	5	480	36.2	2,015	861

*Guns, brooms, mast, etc. were depreciated on a 5-year basis.

†Home assembled.

Comparison of Depreciation Charges by Constant-Percentage and Straight-Line Depreciation Methods

By definition, depreciation represents the decline in value of a machine that results from wear and tear, obsolescence, and inadequacy.¹⁵ Several methods are available for computing the depreciation charge. Two of these methods, and their effect on depreciation and interest charges, were studied for the equipment used on the survey blocks in 1950. Both methods are based on three criteria: the original cost of the machine, the farmer's estimate of its useful life, and the number of previous seasons used. A scrap value of 10 per cent of the original cost is assumed at the end of the machine's useful life. Accessory equipment — such as guns, brooms, masts, or spray heads — was depreciated on a 5-year basis, for these parts must be more frequently replaced than the sprayer itself.

When the straight-line method is used, the machine is depreciated an equal amount in dollars for each year of its normal life. The straight line method assumes that the loss of value through wear and tear, obsolescence, and inadequacy is the same for each year, regardless of age.

The constant-percentage method reduces the value of the machine by subtracting the same percentage of the beginning inventory value for each year of useful life. Thus, the depreciation declines as beginning inventory value decreases from year to year. (The influence of the different methods of computing depreciation for the various types of machines is shown in Appendix tables 4 and 5.)

The method used in computing depreciation had little effect on low cost spray equipment that had been in use for several seasons, with many years of estimated useful life. High-pressure sprayers with guns and brooms were an example of this. Airblast equipment, on the other hand, was relatively new and had a higher original cost, partly because it was purchased in years of higher prices. Hence, the constant-percentage method resulted in higher charges for depreciation and interest, and in higher total spray cost for the airblast machines.

Spray costs in this report include depreciation charges computed by the constant percentage method, which gives the newer equipment — and airblast sprayers in particular — a higher annual equipment cost than does the straight line method. The constant-percentage method, therefore, puts airblast equipment at an apparent disadvantage. Furthermore, a grower buying a new high-pressure sprayer today, would find it more expensive than he would expect from inventory values in the Appendix, tables 2a, 2b, 2c, and 3. All prices have advanced, but differences in the cost of new high-pressure sprayers and airblast equipment would be smaller than the differences in Appendix table 3.

¹⁵Murphy, H. G., and Suter, R. C. Methods of computing depreciation of farm machinery. Dept. Agr. Econ., Cornell Univ. A. E. 729:1. 1950.

Appendix table 3. Investment in spray, dust, and water-supply equipment on the farm
(98 fruit farms in 1949; 108 farms in 1950; New York State)

Type of equipment	Year	Number of farms	Spray and dust equipment*	Water transport rigs†	Perma- nent water supply system	Total equipment and supply system	Invest- ment per acre bearing apples
					Dollars		
Dilute airblast.	1949	27	4,187	480 (16)	464	4,935	81
	1950	36	3,640	499 (22)	782	4,574	67
Concentrate airblast. . .	1950	15	3,863	573 (4)	633	4,607	52
High pressure with guns and/or brooms.	1949	34	1,477	80 (4)	278	1,764	37
	1950	23	981	211 (4)	224	1,222	39
High pressure with masts or spray heads.	1949	19	1,932	375 (4)	264	2,275	58
	1950	17	2,170	231 (3)	353	2,522	51
High pressure with vari- ous outlets.	1949	6	1,898	72 (3)	447	2,381	43
	1950	4	1,196	25 (1)	453	1,655	41
Wet dust.	1949	2	1,364		19	1,383	51
	1950	3	1,902		136	1,992	36
Spray dusters, variously used.	1949	4	2,141	100 (1)	84	2,250	63
	1950	3	1,565		60	1,605	46
Unclassified.	1949	6	2,944	450 (1)	279	3,298	36
	1950	7	2,320		249	2,569	46
All farms.	1949	98	2,452	354 (29)	323	2,880	55
	1950	108	2,591	436 (34)	484	3,150	53
Hudson Valley.	1949	38	1,929	277 (14)	256	2,287	36
	1950	47	2,572	†	†	3,024	48
Western New York. . .	1949	60	2,784	425 (15)	366	3,256	67
	1950	61	2,606	†	†	3,246	56

*Growers' estimate of present value of spray and dust equipment used on the experimental block, plus the value of supplementary spray and dust equipment used on the farm.

†Number in parenthesis indicates actual number of water transport rigs on the farm even if they were not used in the experimental block.

‡Not tabulated for 1950.

Appendix table 4. Effect of method used to arrive at annual depreciation and interest charges for different types of machines

(Straight-line vs. constant-percentage method; 191 machines on survey farms; New York State, 1950)

Type of machine	Machines	Original cost	Previous seasons used	Farmer's estimate of normal life	Depreciation		Interest	
					Straight-line	Constant-Percentage	Straight-line	Constant-percentage
	Number	Dollars	Number	Years	Dollars		Dollars	
Speed sprayer.	30	4,128	1.3	9	429	704	170.59	136.33
Other dilute airblast	8	2,819	0.9	9	285	510	122.02	105.21
Concentrate airblast	15	3,304	0.5	10	324	612	152.40	137.27
High pressure with guns and/or broom	26	1,490	3.8	12	134	168	56.08	41.09
High pressure with masts or spray heads	19	2,162	4.2	12	218	310	93.97	71.64
High pressure with various outlets*. . . .	17	1,509	5.4	14	156	156	51.54	35.58
Spray dusters, variously used.	11	1,781	0.9	9	199	349	75.96	62.73
Supply rig.	22	631	4.0	13	47	71	24.23	19.17
Duster.	43	653	5.1	16	41	53	22.32	16.56

*High pressure: various outlets includes high pressure sprayers used as supplementary equipment on other equipment blocks, and on blocks not classified in a definite category.

Appendix table 5. Effect of the method used to arrive at depreciation cost per acre (Straight-line vs. constant-percentage method; 116 selected blocks of apples; New York State, 1950)

Type of equipment	Blocks	Previous seasons used	Farmer's estimate of normal life	Total cost per acre		Difference in cost with constant-percentage method		
				Straight-line method	Constant-percentage method	Depreciation higher by:	Interest lower by:	Net diff.
	Number	Number	Years	Dollars		Dollars		
Dilute airblast.....	38	1.2	9.3	87.89	91.96	4.87	0.80	4.07
Concentrate airblast.....	16	0.7	9.5	79.25	85.59	6.80	0.46	6.34
High pressure with guns and/or brooms.....	23	4.1	12.2	99.87	100.21	1.04	0.70	0.34
High pressure with masts or spray heads.....	20	3.9	12.0	91.38	94.75	4.39	1.02	3.37
High pressure with various outlets.....	5	5.0	13.2	141.52	142.68	2.36	1.20	1.16
Wet dust.....	4	1.5	8.0	128.31	130.60	3.46	1.17	2.29
Dry dust.....	1	1.0	8.0	116.52	120.86	4.92	0.58	4.34
Spray dusters, variously used.....	3	1.0	10.5	132.66	136.82	4.64	0.48	4.16
Unclassified.....	6	4.5	12.7	76.31	81.88	6.05	0.48	5.57
All blocks.....	116	2.5	10.6	94.20	97.61	4.19	0.78	3.41

Methods Used in the Cost Analysis

Cooperating growers provided all the information for computing both fixed and variable costs for the individual spray operation. The total variable costs were computed. Annual fixed charges were allocated according to the use of all spray and dust equipment on the experimental block, relative to the whole farm operation. The sum of fixed and variable cost for each block was then divided by the number of acres in the block to find the cost per acre, by the number of trees in the block to find the cost per tree, and by the number of 100 gallons applied to find the cost per hundred gallons of dilute spray. All averages presented in this report are simple averages.

Cost of materials

Prices for the different spray and dust materials were obtained from several spray-chemical companies in western New York and in the Hudson Valley. A uniform price list of retail bulk prices was then compiled, to eliminate the effect of minor variations in prices from farm to farm. This made it possible to study variations in cost resulting from different spray practices, and from the use of different equipment types.

Growers recorded the amount of each material used per hundred gallons, along with the number of tanks applied on the experimental block. They also indicated the quantity of dust used and its formula. The physical quantities of each material used were multiplied by the unit price to ascertain the total materials cost.

As a further step in the cost analysis, materials costs were separated according to their use, so that costs of fungicide, insecticide, and hormone materials could be determined.

Cost of labor and tractor power

The number of man hours and the number of tractor hours for the experimental block were also recorded by the grower. The cost of these was calculated by using a uniform rate per hour of labor and tractor use, estimated according to the average on New York cost account farms during the previous year. Hourly rates charged for man labor were 85 cents in 1949 and 92 cents in 1950. The hourly charge for the use of the wheel tractors was 70 cents in 1949 and 72 cents in 1950, for track-laying tractors, \$1.40 in 1949 and \$1.83 in 1950. Thus, for the purpose of this study, tractor cost was treated as a variable cost, rather than as a combination of fixed and variable costs. This simplification seemed justified, since the emphasis of the study is on spray equipment cost.

Cost of spray and dust equipment

The cost of spray and dust equipment was determined by five cost items: (1) annual depreciation charges, (2) annual charges for interest on capital invested in spray equip-

ment, (3) annual cost of repairs, (4) annual cost of oil and grease, and (5) cost of gasoline consumed in operating the equipment on the block. Items 1 through 4 were allocated according to the use of the equipment on the experimental block, relative to its use in the whole orchard operation. The cost of gasoline, item 5, was charged according to the grower's estimate of gasoline used in a 10-hour day.

Cost-analysis sheet

The method used in combining all cost items is illustrated by the form below. The figures represent the operation of one cooperating fruit grower in 1950.

Cost analysis sheet for apple spray project

Type of Equipment and Code Number	Speed Sprayer—2 sides	Block No. 11
Type of Tractor Used	Wheel—100%; Truck—100%; Wheel—100%	Acreage 3.5
		Tree Equivalent 125
		No. of Applications 13
		No. of 100 gallons 227.00

Equipment usage

Equipment	Code No.	Equip. Hours	Number Men	Labor Hours	Tractor Hours		Truck Hours	Block (T)—No.	Total (T)—No.	Per cent of Total
					Wheel	Cat.				
Speed Sprayer		12.15	1	12.15	12.15	—	—	45.40	372	12.2
Servicing				.61						
Sub-Total		12.15	XXXX	12.76	12.15	—	—	45.40	372	12.2
Duster		.50	2	1.00	.50	—	—	250	600	41.7
Supply Rig		12.15	1	12.15	—	—	12.15	—	—	12.2
Total		24.80	XX	25.91	12.65	—	12.15	XX	XX	

Fixed costs on equipment, in dollars

Equipment	Orig. Cost	Seasons Used	Est. Life	Begin. Value	End Value	Aver. Value	Deprec. Charge
Speed Sprayer	4154	1	6	2830	1929	2380	901
Supply Rig	175	8	10	28	22	25	6
Duster	S.H. 450	4	5	243	209	226	34
Repair parts						10	
						2390	901
						25	6
Total Investment and Depreciation						226	34
						119.50	
						1.25	XXXX
Interest Charge @ 5 per cent						11.30	

Operating costs on equipment, in dollars

Equipment	Gallons Gas/10 Hrs	Gallons on Block	Annual Oil & Grease Expense	O & G on Block	Annual Repairs	Repairs on Block
Bean Speed Sprayer	45	54.68	14	1.71	25	3.05
Home assembled supply rig	2	2.43	2	.24	20	2.44
Niagara Duster	10	.50	2	.83	13	5.42
Total	XXXX	57.61	XXXX	2.78	XXXX	10.91

Summary of costs, in dollars

Items	Total Block	Per Acre	Per 100 gals.	Per Tree	% of Total
Materials	198.93	56.837	.876	1.591	48.7
Labor cost @ \$.92 per hr.	23.84	6.811	.105	.191	5.8
Power cost \$.72	17.86	5.103	.079	.143	4.4
Equipment cost:					
Depreciation 124.83		35.666	.550	.999	30.6
Interest 19.44		5.555	.086	.156	4.7
Repairs 10.91		3.117	.048	.087	2.7
Oil & grease 2.78		.794	.012	.022	.7
Gasoline @ 17c 9.79		2.797	.043	.078	2.4
Total 167.75		47.929	.739	1.342	41.1
Total Cost 408.38		116.680	1.799	3.267	100.0

